ASSESSING THE THREAT OF INFECTIOUS DISEASE TO
THE BIOSECURITY OF THE UNITED STATES

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There are four significant variables that must be considered when assessing the biosecurity threat of infectious disease to the US. Climate change, globalization, bioterrorism and policy all have a variance of impact that must be considered to prevent an outbreak of disease. Diseases such as Ebola, Zika, anthrax, and measles, have all had recent impact on the biosecurity of the US. Climate change is having an effect upon the habitat of many arthropod vectors of disease. Global travel and human migration are increasing the ranges of many infectious diseases of global significance. After the attacks of September 11th, 2001, the US has increased efforts to identify and combat bioterrorism. Health policies that address vaccinations have come under scrutiny. When diseases are assessed against the four variables, the vulnerability of public health prevention and response efforts can be assessed and identified as "gaps." Once identified, gaps in biosecurity can be mitigated to prevent or lessen the impact of future outbreaks of infectious disease.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

ASSESSING THE THREAT OF INFECTIOUS DISEASE TO THE BIOSECURITY OF THE UNITED STATES, by Major John M. Lopez, 100 pages.

There are four significant variables that must be considered when assessing the biosecurity threat of infectious disease to the US. Climate change, globalization, bioterrorism and policy all have a variance of impact that must be considered to prevent an outbreak of disease. Diseases such as Ebola, Zika, anthrax, and measles, have all had recent impact on the biosecurity of the US. Climate change is having an effect upon the habitat of many arthropod vectors of disease. Global travel and human migration are increasing the ranges of many infectious diseases of global significance. After the attacks of September 11th, 2001, the US has increased efforts to identify and combat bioterrorism. Health policies that address vaccinations have come under scrutiny. When diseases are assessed against the four variables, the vulnerability of public health prevention and response efforts can be assessed and identified as "gaps." Once identified, gaps in biosecurity can be mitigated to prevent or lessen the impact of future outbreaks of infectious disease.

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ACRONYMS

CDC	Centers for Disease Control and Prevention
IDTM	Infectious Disease Threat Matrix
MIDRP	Military Infectious Diseases Research Program
US	United States
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

> To stop disease that spreads across borders, we must strengthen our systems of public health. We will focus on the health of mothers and children. And we must come together to prevent, detect, and fight every kind of biological danger—whether it is a pandemic like H1N1, a terrorist threat, or a treatable disease.
>
> — President Barack Obama, September 21st, 2011, Address to the United Nations General Assembly

Problem Identified

The threat from infectious disease to the security of the United States (US) has always been present. Threats can come in a variety of forms. Infectious diseases deliberately released against a population, referred to as bioterrorism, or against agriculture, a subset of bioterrorism referred to as agroterrorism, are what the nation spends a great deal of resources to prepare, respond and recover from. Bioterrorist agents can inflict the most fear upon our national security as witnessed with the anthrax letter attacks following the events of September 11th, 2001.[1] Since then the US has allocated resources combating potential bioterrorist weapons, but infectious diseases can pose just a significant threat through many other means. Normally occurring infectious disease from foreign countries can enter the US through human migration[2], global travel[3] or

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[1] The Center for Food Security and Public Health, "Anthrax" (Information Paper, College of Veterinary Medicine Iowa State University, Ames, 2007), 1.

[2] Brian D Gushulak, J. Weekers, and Douglas W. Maspherson, "Migrants and Emerging Public Health Issues in a Globalized World: Threats, Risks and Challenges, an Evidence-Based Framework," *Emerging Health Threats Journal* 2 (March 2010): 4.

[3] Karen S. Moore, "International Travelers and Infectious Disease," *The Journal for Nurse Practitioners* 11, no. 1 (January 2015): 56.

through a vector host such as a mosquito or tick.[4] Infectious diseases may also inflict a greater burden of mortality and morbidity from within. Vaccine preventable outbreaks are occurring with more regularity in the US and infections acquired within a hospital setting are also placing an economic burden on the US healthcare infrastructure.[5]

Globalization, international travel, and climate change exacerbate the issues presented by infectious disease.[6] As the world continues to shrink, with more Americans traveling abroad, and foreign visitors choosing the US as their vacation destination of choice, infectious disease continue to challenge the institutions that are in place to combat them.[7] Climate change has also increased the range of habitat of vectors capable of transmitting a host of vector-borne disease that can infect both agriculture and human populations.

The current preparation and response to infectious disease is split between two lines of effort. The first line views infectious diseases against their use as weapons of mass destruction. The diseases most considered for use as a bioterror weapon are anthrax

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[4] Atul Khasnis and Mary D. Nettleman, "Global Warming and Infectious Disease," *Archives of Medical Research* 36, no. 6 (November-December 2005): 694-695.

[5] R. Douglas Scott II, *The Direct Medical Costs of Healthcare-Associated Infections in U.S. Hospitals* (Report, Atlanta: Division of Healthcare Quality Promotion National Center for Preparedness, Centers for Disease Control and Prevention, 2009).

[6] Celia McMichael, Jon Barnett, and Anthony J. McMichael, "An Ill Wind? Climate Change, Migration and Health," *Environmental Health Perspectives* 120, no. 5 (May 2012): 646-654.

[7] Stephen S. Morse, "Factors in the Emergence of Infectious Diseases," *Emerging Infectious Diseases* 1, no. 1 (January-March 1995): 11-12.

and smallpox.[8] The second line of effort views infectious disease and the potential to infect a given population from all other means but deliberate. This could include historically significant tropical diseases such as Malaria and Dengue, expanding their habitat as a direct effect of climate change.[9]

In the current environment of human migration, the US is beginning to see an influx of illegal immigrants from places other than Mexico; these places include Central and South American countries such as Guatemala, El Salvador, Honduras, and Ecuador, as well as immigrants from Caribbean countries such as Cuba, Jamaica and Haiti.[10] For reasons such as climate change, economics, safety, or the chance of a more prosperous life, these immigrants are making their way to the US.[11] These countries do not have robust disease surveillance monitoring programs or treatment capabilities, so many diseases that are rare in the US are endemic to these countries.

The US has a growing sub population of citizens that refuse vaccinations based on medical, religious, or personal beliefs.[12] This population is most at risk for compounding

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[8] Lisa D. Rotz et al., “Public Health Assessment of Potential Biological Terrorism Agents,” *Emerging Infectious Diseases* 8, no. 2 (February 2002): 227.

[9] National Intelligence Council, *The Global Infectious Disease Threat and Its Implications for the United States* (Washington, DC: National Intelligence Council, 2000), 55-58.

[10] John F. Simanski, *Annual Report: Immigration Enforcement Actions* (Washington, DC: Office of Immigration Statistics, Department of Homeland Security, 2013).

[11] Cathy Zimmerman, Ligia Kiss, and Mazeda Hossain, “Migration and Health: A Framework for 21st Century Policy-Making,” *PLoS Medicine* 8, no. 5 (May 2011): 1-7.

[12] Jeffrey Levi et al., *Outbreaks: Protecting Americans From Infectious Disease 2015* (Menlo Park: Robert Wood Johnson Foundation, 2015).

the effects of introducing a re-emergent or vaccine preventable disease into the population. Global travelers residing in or visiting endemic disease countries can become infected and carry the disease with them to the US.[13] These travelers subject unvaccinated populations to preventable disease and in some cases, such as measles, the disease organism is highly contagious and can intensify an epidemic amongst an unvaccinated population.

This study will analyze the threat of infectious disease across these many domains against the susceptibility of the US population in the hopes of identifying potential gaps that can be addressed with an update to the emergence, detection and response protocol used as the framework for a national response plan.[14] This study will also address climate change, global travel and-or bioterrorism and provide analysis as to which, if any, poses the most significant threat to the biosecurity of the US. In terms of biosecurity threat, this study will analyze it from three perspectives; the ability of the disease to produce high mortality and-or morbidity to the population; the ability of the disease threat to cause public panic in response to the organism; and from the potential for the disease to cause economic burden either through the costs to the healthcare infrastructure to treat and contain the disease or indirectly from the economic burden that can be created through the disruption to livestock, crops, and-or agricultural infrastructure.

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[13] Jennifer Zipprich et al., "Measles Outbreak-California, December 2014-February 2015," *Morbidity and Mortality Weekly Report*. 64, no. 6 (2015): 153-154.

[14] The Henry J. Kaiser Family Foundation, *The U.S. Government and Global Emerging Infectious Disease Preparedness and Response* (Menlo Park: The Henry J. Kaiser Family Foundation, 2014).

Research Question

This study asks: How can we assess threats and identify gaps in the biosecurity preparedness of infectious diseases to the US general population and military forces given the effects of climate change, human migration, global travel and a subpopulation of unvaccinated individuals? As current events such as the threat and realization of Ebola reaching US shores from West Africa, to the even more current threat that the Zika virus poses to reproducing females, it has become even more evident that the US needs to seek to close gaps in biosecurity from an infectious disease standpoint.

Secondary Questions

1. What is the magnitude and scope of the biosecurity threat faced by the US with respect to infectious disease based on Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) guidelines?

This question seeks to identify the potential disease agents that can directly or indirectly effect the US population, the manner at which they may enter the US if they are not already endemic, and the impact of globalization on infectious disease. These effects can be direct, such as targeting the mortality or increasing the morbidity of a given population in the US. Direct effects can also be attributed to a direct attack upon the economy, for instance, an agroterrorist attack aimed at livestock producing farms which could stop trade or incur a direct financial loss to the farms themselves.[15]

[15] Peter Ndeboc Fonkwo, "Pricing Infectious Disease; The Economic and Health Implpications of Infectious Disease," *European Molecular Biology Organization* 9 (Special Issue 2008): Table 3.

There are many diseases that can increase their ranges through vector or host migration and increase the potential to infect new populations. Globalization includes all movement of persons that travel in and out of the US or enter illegally. One theory is that the undocumented (illegal) migrant population poses the most significant threat; however, the magnitude of tourist travel may seem to outweigh the threat.[16] In either case, globalization may aid in the spread of disease by increasing the amount of contact between people within an endemic region.

2. Are there any current disease risk identification tools used by the US or the US Armed Forces that focus on biosecurity?

This question seeks to identify gaps that may be present in the national framework of preparedness for emergence, detection and response to an outbreak of infectious disease. The study will identify any gaps in the preparedness framework of emergence, detection and response to biosecurity in the civilian sector and with respect to the military's approaches towards combating infectious disease.

Assumptions

There are five significant assumptions that this study will take into account in measuring biosecurity threat. These assumptions are necessary to understand the intricacies of infectious organisms and their ability to affect so many institutes of economy and health. The assumptions address the categorical contexts of habitat change, susceptible populations, and policy.

[16] Louis Jacobson, "Are Illegal Immigrants Bringing 'Tremendous' Disease across the Border, as Trump Says? Unlikely," Politifact, July 23, 2015, accessed May 23, 2016, http://www.politifact.com/truth-o-meter/article/2015/jul/23/are-illegal-immigrants-bringing-tremendous-diseas/.

The most significant assumption is that an infectious disease will persistently threaten the biosecurity of the US. History supports the proposition that infectious disease will continue to threaten the US. During the last 100 years the US has witnessed infectious diseases used as a bioterror agent three times. The first incident was an attack by two terrorists on the Chicago public water supply. The second involved a religious cult lacing salad bars with salmonella in Oregon and the third, were the 2011 Anthrax letter attacks.[17] Over the same 100 years the US has witnessed three pandemic outbreaks. The first was the Spanish Flu pandemic that began in the US at Fort Riley, Kansas. The second flu pandemic, this one labeled the Asian Flu Pandemic occurred in the 1950s and killed nearly 70,000 Americans. The third pandemic is the AIDS pandemic that began in the 1980s and has killed millions globally.[18] The US continually has to address endemic disease issues.[19] Diseases will continue to emerge and many have the potential to adapt to current drug and treatment protocols.

Another significant assumption is that climate change is occurring. Recent evidence produced by the IPCC has shown that the change in climate over the past 100 years is a result of human action and has caused the average global temperature to rise

[17] Texas Department of State Health Services, "History of Bioterrorism," March 11, 2015, accessed January 11, 2016, https://dshs.state.tx.us/preparedness/bt_public_history.shtm.

[18] Robert Wood Johnson Foundation, "The Five Deadliest Outbreaks and Pandemics in History," December 16, 2013, accessed February 3, 2016, http://www.rwjf.org/en/culture-of-health/2013/12/the_five_deadliesto.html.

[19] Levi et al.

over 1.4 degrees Celsius.[20] Due to human action, the change in climate over the course of the last 100 years has changed faster than at any time in the last 800,000 years on earth.[21] The reason for the climate change, whether it be naturally occurring or a manmade event is not the purpose of this study. Rather, it is important to understand the link between the change in climate and the indirect and direct effects on population migration, expanding disease vector ranges, and changes that climate may cause to the physiology of disease agents and vectors.

Climate change may also have a socioeconomic factor that will not be a focus of this study. Climate change has been linked to significant adverse weather patterns, food insecurities, and a global need for resources. Globally, migration can be associated the desires for a more stable environment. Violence, natural disasters, resource insecurities, and economic prosperity have all been reasons for migration.[22]

Healthcare costs will continue to rise irrespective of the impact of infectious disease. Healthcare costs are rising as non-communicable disease such as diabetes; heart disease and obesity have surpassed infectious disease as the highest causes of mortality and morbidity in the US. In 2014, the US spent a total of $3 trillion on healthcare which amounts $9,523 per capita and equates to 17.5 percent of the gross domestic product of

[20] Core Writing Team, Rajendra K. Pachauri, and Leo A. Meyer, eds., *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of theIntergovernmental Panel on Climate Change* (Geneva: IPCC, 2014).

[21] Ibid.

[22] The LEVIN Institute, "Globalization 101," A Project of the SUNY LEVIN Institute, 2016, accessed May 25, 2016, http://www.globalization101.org.

the US.[23] Healthcare spending has an annual growth of 7 to 8 percent and is expected to reach $5 trillion annual or 20 percent of the gross domestic product by 2021.[24] The increase in spending comes without significant increase to daily life expectancy or the US population.[25] Costs for communicable disease mitigation will continue to grow and increase substantially during response measures as was witnessed in the US during the Ebola outbreak.[26]

Individual States will continue to be responsible for enacting vaccination laws for school-aged children. In response to the most recent outbreak of measles within their state, California recently passed Senate Bill 277 which eliminated religious and personal vaccine exemptions.[27] More states may follow California's response at addressing herd immunity and vaccine preventable disease and pass their own laws eliminating some exemptions.

Globalization will continue to provide more opportunity for the spread of infectious diseases. It is predicted that globalization will lead to the creation of more

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[23] Centers for Disease Control and Prevention, "Health Expenditures," April 27, 2016, accessed May 23, 2016, http://www.cdc.gov/nchs/fastats/health-expenditures.htm.

[24] Robert Wood Johnson Foundation, *Health Policy Snapshot Healthcare Costs* (Princeton: Robert Wood Johnson Foundation, 2011).

[25] The Henry J. Kaiser Family Foundation, "Health Spending in the U.S. As Compared to Other Countries Slideshow," accessed May 23, 2016, http://kff.org/slideshow/health-spending-in-the-u-s-as-compared-to-other-countries-slideshow/.

[26] Alexandra Sifferlin, "Here's How Much the Next Ebola Will Cost Us," *Time*, December 16, 2014, 1-2.

[27] California State Legislature, "SB-277 Public Health: Vaccinations," June 30, 2015, accessed May 23, 2016, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB277.

megacities around the globe.[28] Megacities can foster economic instability, create substandard living conditions for more residents, challenge the public health systems, and lead to more opportunity for diseases to spread within communities. Overcrowding that occurs in megacities could lead to more incidence of communicable disease transmission. The increased person to person contacts could quickly escalate a virulent outbreak to a global pandemic.

Key Terms

Agroterrorism: A subset of bioterrorism, defined as "the deliberate introduction of an animal or plant disease for the purpose of generating fear, causing economic losses, or undermining social stability."[29] It represents a tactic to attack the economic stability of the US. Killing livestock and plants or contaminating food can help terrorists cause economic crises in the agriculture and food industries. Secondary goals include social unrest and loss of confidence in government.

Biosecurity: Measures that are taken to stop the spread or introduction of harmful organisms to human, animal and plant life. The measures taken are a combination of processes and systems that have been put in place by bioscience laboratories, customs agents and agricultural managers to prevent the use of dangerous pathogens and toxins.

Bioterrorism: Deliberate release of viruses, bacteria, or other germs to cause illness or death. These germs are often found in nature. But they can sometimes be made

[28] Gushulak, Weekers, and Maspherson, 1-12.

[29] Dean Olson, *Agroterrorism: Threats to America's Economy and Food Supply* (Quantico: Federal Bureau of Investigation, 2012).

more harmful by increasing their ability to cause disease, spread, or resist medical treatment.

Climate Change: Refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer.

Communicable Disease: An illness due to a specific infectious agent or its toxic products that arises through transmission of that agent or its products from an infected person, animal or inanimate reservoir to a susceptible host; either directly or indirectly through an intermediate plant or animal host, vector or the inanimate environment.

Emerging Infectious Disease: An infectious disease that is newly recognized as occurring in humans; one that has been recognized before but is newly appearing in a different population or geographic area than previously affected; one that is newly affecting many individuals; and-or one that has developed new attributes (e.g., resistance or virulence).

Endemic: The constant presence of a disease or infectious agent within a given geographic area; it may also refer to the usual prevalence of a given disease within such area.

Epidemic: The occurrence in a community or region of cases of illness (or an outbreak) with a frequency clearly in excess of normal expectancy. A single case of a communicable disease not previously recognized in that area requires immediate reporting and epidemiological investigation; two cases of such a disease associated in time and place are sufficient evidence of transmission to be considered an epidemic.

Incidence: A measure of disease; a person's probability of being diagnosed with a disease during a given period of time.

Incubation period: Time interval between initial contact with an infectious agent and the first appearance of symptoms associated with the infection.

Infectivity: The ability of the disease agent to enter, survive and multiply in the host; infectiousness indicates the relative ease with which a disease is transmitted to other hosts.

Legal Residents: Includes all persons granted lawful permanent residence; granted asylum; admitted as refugees; or admitted as nonimmigrants, such as students or temporary workers.

Morbidity: A term for illness. Prevalence is a measure often used to determine the level of morbidity in a population and daily adjusted life years (DALY) is often used as an individual measure.

Mortality: Term used to identify death in a population. A mortality rate is the number of deaths due to a disease divided by the total population infected by the same disease.

Nosocomial Infection: An infection from one of various microorganisms that is acquired while a patient in a hospital.

Pathogenicity: The property of an infectious disease agent that determines the extent to which overt disease is produced in an infected population, or the power of an organism to produce disease.

Prevalence: A person's likelihood of having a specific disease. A prevalence rate is the total number of cases of a disease existing in a population divided by the total population.

Temporary Legal Residents: Includes persons who are granted temporary legal stay such as students, diplomats or temporary workers.

Unauthorized Residents: All foreign-born non-citizens who are not legal residents.

Vaccine Preventable Disease: Diseases that can be prevented with available vaccines.

Vector-borne Disease: infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, sandflies, and blackflies. Arthropod vectors are cold-blooded (ectothermic) and thus especially sensitive to climatic factors. Weather influences survival and reproduction rates of vectors; in turn influencing habitat suitability, distribution and abundance; intensity and temporal pattern of vector activity (particularly biting rates) throughout the year; and rates of development, survival and reproduction of pathogens within vectors. However, climate is only one of many factors influencing vector distribution, such as habitat destruction, land use, pesticide application, and host density.

Virulence: The degree of pathogenicity of an infectious agent, indicated by case fatality rates and-or the ability of the agent to invade and damage tissues of the host.

Limitations and Delimitations

This study is limited to open sourced documents from peer reviewed articles and studies that evaluate threats, media reports, and unclassified government materials primarily dealing with the funding of bio surveillance, population statistics, preparedness and planning measures and response protocols. This study is also limited to diseases that pose a threat to national biosecurity. The threats being evaluated are;

1. public safety from morbidity and mortality,
2. The potential for causing panic and civil disruption, and
3. the ability of the organism to cause significant economic distress either to healthcare or economics.

Significance of Study

The US spends over $120 billion each year directly combating infectious disease.[30] This figure includes indirect costs such as the lost productivity of sick workers or the policies created as a result of trying to contain a disease. The United States Department of Agriculture estimates if a hoof-and-mouth disease outbreak occurred in the US, it could cost the livestock industry $20 billion over 15 years.[31] Crop diseases alone account for an estimated $30-billion-dollar loss annually.[32] These costs alone are staggering and directly affect the economy of the US.

Preparing for a potential infectious outbreak or natural disaster is a mission for the United States Army. Defense Support of Civil Authorities or Stability operations in contingency areas will require commanders to identify and mitigate the risks of infectious

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[30] Levi et al.

[31] National Intelligence Council.

[32] O. Shawn Cupp, David E. Walker, and John Hillison, "Agroterrorism in the U.S.: Key Security Challenge for the 21st Century," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 2, no. 2 (2004): 100.

disease to the population and deployed forces.[33] Creating an infectious disease threat matrix will enable the commanders to get an accurate picture of the environment and identify challenges and opportunities presented by infectious disease. Public health departments across the US may also benefit from the use of a disease threat matrix. Many rural public health departments, especially those on the southern borders with Mexico and the Caribbean, will be on the front lines combating emerging infectious diseases. A threat matrix may assist response plans to infectious disease outbreaks.

The results could highlight opportunities for the Army to assist in the development of national response plans for disease outbreaks. The US Army can expand partnerships with other government and private agencies to create new vaccines, treatments, and increased surveillance capability to combat communicable disease.[34] The US Army can provide subject matter experts to increase civilian capacity of response to an infectious disease threat; this would allow for a strengthened Defense Support of Civil Authorities response capability. The US Army also has the capability of continued research in global infectious disease surveillance, treatments and response.[35] These

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[33] Headquarters, Department of the Army, Army Doctrine Publication (ADP) 3-28, *Defense Support of Civil Authorities* (Washington, DC: Department of the Army, 2012).

[34] U.S. Army Medical Research and Material Command, "Military Infectious Diseases Research Program (MIDRP)," March 22, 2010, accessed May 23, 2016, http://mrmc.amedd.army.mil/index.cfm?pageid=medical_r_and_d.midrp.overview.

[35] U.S. Army Medical Research and Material Command.

capabilities could be critical in the event of a domestic epidemic as was the case with the recent Ebola outbreak.[36]

Conclusion

This study is important to the overall security of the US. Threats from disease can come in a myriad of forms, from terrorists employing bioweapons to innocent tourists who unknowingly transmit a potentially deadly pathogen to a susceptible person. The threat is significant. In the US response triad of emergence, detection and response, most resources are allocated to detection and surveillance. This focus on surveillance allows the US public health sector to be able to respond to outbreaks more quickly. The responses to some diseases can come at great financial cost. Chapter 2 will discuss the data needed to identify and evaluate the threat of communicable disease against the population and economy of the US.

[36] U.S. Army Medicine, "Army Medicine's Ebola Response: We are Prepared, Capable and Composed," *Mercury* Special Supplement (November 2014): 1-13.

CHAPTER 2

LITERATURE REVIEW

Restated Purpose of Research

The purpose of this study is to evaluate the threat of infectious disease to the biosecurity of the US population with respect to climate change, globalization, human migration and unvaccinated populations. This study will seek to identify gaps in biosecurity. The gaps identified could identify needs for further research, potential mitigation strategies, and provide for an overall risk assessment of a disease to a given population.

Organization

Chapter 2 will look at the current population of the US and will provide some statistics of the number of travelers and immigrants that are entering and leaving the US on an annual basis. These populations of travelers and migrants could be a potential catalyst to the spread of a disease agent those pathogens that might be endemic to their country of origin or country visited.

This chapter will also identify some of the disease pathogens of most concern to the CDC, Department of Defense, Department of Homeland Security, and WHO. Concern will be measured in the potential of the organism to cause high mortality or morbidity in the host population, to cause significant economic distress in the agricultural sector, or the disease organism's ability to be used as a bioterrorist weapon. As the most significant threats are identified, the costs to prevent, detect and respond to them must be evaluated.

The total costs of managing disease outbreaks could be identified as a gap in response efforts. The total costs consumed when preventing and responding to outbreaks of disease can be broken down into direct and indirect costs. Direct costs include the resources, services, and surveillance costs required to respond to outbreaks. These costs are easier to attain because there is a monetary amount assigned to them. Indirect costs such as lost work time and wages for patients, decreased productivity, children missing school and economic disruption, are difficult to measure monetary effects against.

Disease Cycle

For the purpose of this paper it is important to understand a generalized disease cycle of infection. This interpretation of a generalized disease cycle holds true for many infectious disease organisms that may pose a threat to people and animals. First, an individual needs exposure to an infectious disease agent. The exposure can take many forms, but typical routes include inhalation, ingestion, direct contact or from the bite of a vector.

Bioweapons typically use inhalation as a means of dissemination.[37] Anthrax is classified as an inhalation agent of disease. The anthrax bacterium produces a spore which allows it to survive in the air or ground for a significant period of time.[38] When used as a bioweapon it can infect the lungs when inhaled by a susceptible individual. Ingested infectious organisms are typical of food and waterborne disease. Ingested

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[37] GlobalSecurity, "Weapons of Mass Destruction (WMD), Biological Warfare Agent Delivery," July 24, 2011, accessed May 23, 2016, http://www.globalsecurity.org/wmd/intro/bio_delivery.htm.

[38] The Center for Food Security and Public Health, "Anthrax."

organisms tend to cause gastrointestinal issues in the infected host and some common examples include salmonella and *Escherichia coli*.

Vector borne disease are transmitted through the bites of arthropods and other insects. Typical vectors responsible for transmitting disease and an example of the disease are fleas which may transmit bubonic plague; mosquitoes which transmit a plethora of diseases to include Malaria, Zika, Dengue Fever, and Chikungunya; and Lyme Disease which can be transmitted through the bite of certain ticks.

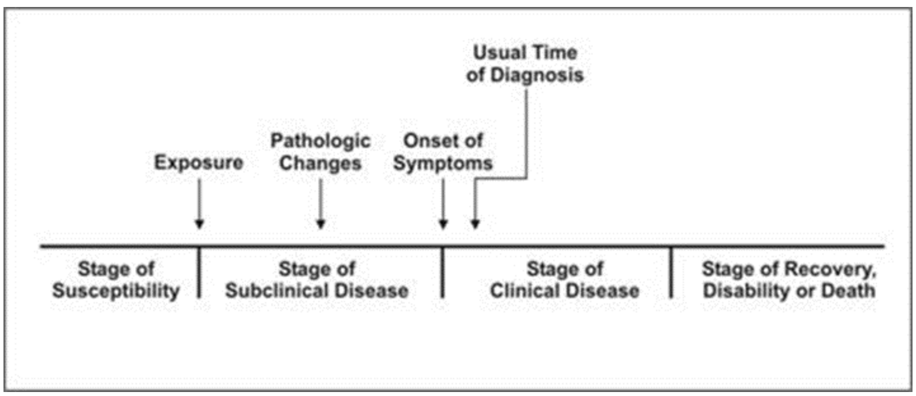

Figure 1. Disease Lifecycle

Source: Centers for Disease Control and Prevention, “2016 Nationally Notifiable Infectious Diseases,” January 21, 2016, accessed February 3, 2016, http://wwwn.cdc.gov/nndss/conditions/notifiable/2016/infectious-diseases/.

Note: This is a representation on the disease lifecycle causing infection in a susceptible individual.

Once a susceptible individual (host) is exposed to the disease agent, the disease organism will begin to replicate within the new host (figure 1). The organism may replicate in enough quantity within the host and cause symptoms of disease (figure 1). The infected host either fights off or succumbs to the disease; these are notated as stage of recovery, disability, or death in (figure. 1). During the entire disease process the newly infected host may be infectious to others during the subclinical to recovery stages of the disease cycle.

Population Data and Demographics

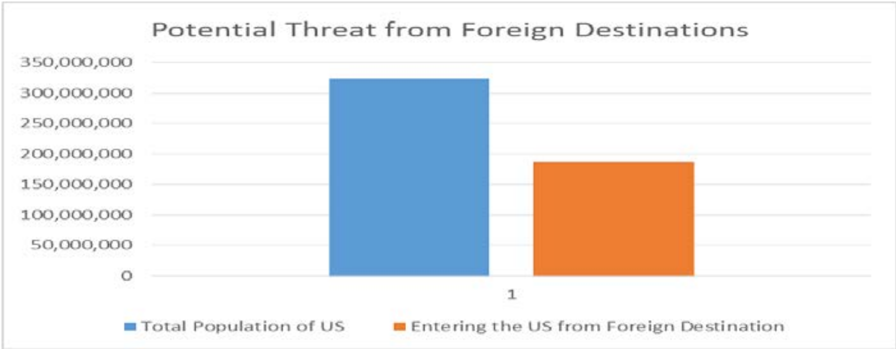

Figure 2. Population Movement Data

Source: Compiled by author, data from International Trade Administration Industry and Analysis, *International Visitation to the United States: A Statistical Summary of U.S. Visitation (2014)* (Washington, DC: U.S. Department of Commerce, 2014); National Travel and Tourism Office, *2014 Market Profile: U.S. Outbound to Overseas* (Washington, DC: U.S. Department of Commerce, 2014); Jeffrey S. Passel and D'vera Cohn, *Unauthorized Immigrant Totals Rise in 7 States, Fall in 14: Decline in Those From Mexico Fuels Most State Decreases* (Washington, DC: Pew Research Center's Hispanic Trends Project, November 2014); John F. Simanski, *Annual Report: Immigration Enforcement Actions* (Washington, DC: Office of Immigration Statistics, Department of Homeland Security, 2013).

Note: Depicts the number of people entering the US from foreign soil annually for all reasons. The bar chart highlights the ratio of the total population of the US to those that enter from a foreign destination annually.

This figure highlights a potential threat from international travelers and migrants into the US. Most of the US population resides in larger urban settings. The largest potential for introducing an infectious disease upon the US population comes from overseas travelers either residing or visiting the US. These numbers are 68.2 million foreign visitors to the US and 74.8 million international US travelers.[39] Of the foreign visitors to the US roughly 41 million are from Mexico and Latin America; Europe and Asia make up the next largest groups at 13 million and 9.5 million visitors annually.[40]

The top two destinations of choice for the 74.8 million travelers from the US are to visit Europe (35 percent) and the Caribbean (24 percent). South and Central America make up roughly (15 percent) of US travelers.[41] It is important to note the locations that international and US travelers visit, as many opportunistic or emerging (reemerging) diseases are endemic to these locations.[42]

Infectious Disease Threats

Bioterrorism—This class of threats include agents that could be used by and individual, group or state actor to incite fear or death to a US population or for the purpose of expanding one's own personal or political agenda. Roughly twenty-one countries around the world are thought to or have had a biological weapons program.[43]

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[39] International Trade Administration Industry and Analysis, *International Visitation to the United States: A Statistical Summary of U.S. Visitation (2014*) (Washington, DC: U.S. Department of Commerce, 2014).

[40] Ibid.

[41] National Travel and Tourism Office, *2014 Market Profile: U.S. Outbound to Overseas* (Washington, DC: U.S. Department of Commerce, 2014).

[42] GlobalIncidentMap.com, "Outbreaks," accessed May 25, 2016, http://outbreaks.globalincidentmap.com/.

[43] James Martin Center for Nonproliferation Studies (CNS) "Chemical and Biological Weapons: Possession and Programs Past and Present," March 2008, accessed May 25, 2016, http://www.nonproliferation.org/chemical-and-biological-weapons-possession-and-programs-past-and-present/.

Biological weapons are less expensive and require less technical expertise to develop than nuclear weapons. In the right circumstance biological weapons can produce a similar effect of death and panic in a targeted population as nuclear weapons. In a 1993 report of the United States Congressional Office of Technological Assessment, it was estimated that a release of 100kg of weaponized anthrax spores over the Washington, DC metropolitan area, could lead to the deaths of 130,000 to three million deaths depending on response and treatment availability.[44] The CDC estimated the economic impact of such an attack to be $26.2 billion per 100,000 individuals exposed to the attack,[45] and given a population of 6.1 million residents in the Washington DC area,[46] the effects could be staggering.

When infectious agents are used as a means to incite fear or to progress a political or ideological agenda these weapons them become agents of terror, referred to as bioterrorism. Since the terrorist attacks of September 11th, 2001 and the anthrax bioterrorist attacks in the same year, the US government has invested significant resources in developing prevention and response measures to combat potential bioterrorist attacks. The Department of Homeland Security is now the lead agency for combating threats from bioterrorism through various departments of the CDC, Department of Defense and NIH.

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[44] Thomas V. Inglesby et al., "Anthrax as a Biological Weapon Medical and Public Health Management," *JAMA* 281, no. 18 (May 1999): 1735-1745.

[45] Ibid.

[46] Benjamin Freed, "Census: Washington Metro Area Is Now Larger Than Philadelphia Metro Area," *Washingtonian*, March 24, 2016, accessed May 23, 2016, https://www.washingtonian.com/2016/03/24/census-washington-metro-area-is-now-larger-than-philadelphia-metro-area/.

Table 1. Categorization of Disease for this Study

Category A	Category B	Category C
*Easily disseminated or transmitted person to person	*Moderately easy to disseminate	*Relative ease of dissemination
*Can cause high mortality	*Can cause moderate morbidity and low mortality	*Potential for high morbidity and mortality
*Can cause widespread public panic	*Can cause localized panic	*Minimal public panic
Examples	**Examples**	**Examples**
Smallpox	Equine encephalitis	Hanatvirus
Anthrax	Escherichia coli	Tickborne disease
Plague	Cryptosporidium	Yellow fever
Botulism toxin	Cholera	Drug-resistant tuberculosis
Ebola		

Source: Centers for Disease Control and Prevention, *Preventing Emerging Infectious Disease: A Strategy for the 21st Century Overview of the Updated CDC Plan* (Atlanta: Centers for Disease Control and Prevention, 1998).

Note: CDC threat categories for infectious disease based on the disease organism ability to cause morbidity, mortality, or widespread public panic. The threat from Category A organisms are most significant, followed by Category B and Category C organisms.

Table 1 represents the CDC's categorization of the disease agents that pose the most direct biosecurity risk from a bioterrorist threat.[47] The CDC identifies organisms that either cause high morbidity and-or high mortality, or have the potential to create panic in the population. As is evident from CDC studies, each of these agents can be easily produced or can be easily disseminated. This table is organized so that Category A agents pose the most significant threat as a bioterrorist weapon and Category C the lesser

[47] Ali S. Khan, Alexandra M. Levitt, and Michael J. Sage, *MMWR: Biological and Chemical Terrorism: Strategic Plan for Preparedness and Response; Recommendations of the CDC Strategic Planning Workgroup* (Atlanta: Centers for Disease Control and Prevention, 2000).

of the three categories. One variable that the CDC does not assess is the economic burden of these disease categories in preparedness and response efforts.

Table 2. CDC List of Potential Bioterror Diseases

Bioterror Infectious Disease	**Emerging/Reemerging Disease**	**Vaccine Preventable Disease**	**Opportunistic Disease**
Anthrax	Avian influenza A (H5N1)(H7N9)	Measles	Hospital acquired infections
Smallpox	MERS-Coronavirus (MERS-CoV)	Pertussis	-Clostridium difficile (C. diff)
Botulism	Dengue Hemoragic Fever	Yellow fever	-Methilcilian resistant staphylococcus aureus (MRSA)
	Ebola	Hepatitis A, B, C	Drug resistant organisms
Agricultural Disease of Significance (Agroterrorsim)	Zika	Diptheria	-Drug resistant tuberculosis
Creutzfeldt-Jakob Disease (Mad Cow Disease)	Plague		-super bugs
Cryptosporidiosis	Hanta Virus		
Salmonella	Malaria		
Escherichi coli	Chikungunya		
Rabies	Lyme		
Typhoid	West Nile Virus		
Cholera	HIV		
Brucellosis	Severe Acute Respiratory Syndrome-Associated Coronavirus Disease (SARS)		
Western and Eastern Equine Encephalitis			

Source: Created by author, compiled data from Centers for Disease Control and Prevention, “2016 Nationally Notifiable Infectious Diseases,” January 21, 2016, accessed February 3, 2016, http://wwwn.cdc.gov/nndss/conditions/notifiable/2016/infectious-diseases/.

Note: Showcases the most significant infectious disease organisms by category of overall threat

Table 2 categorizes and lists the disease pathogens that pose the largest threat to the biosecurity of the US. Some of these diseases may overlap into other categories, for example, if a terrorist were to use an infected Ebola patient or their bodily fluids in a capacity to purposefully infect a population, then the Ebola could be considered a potential bioterror disease. Many of the agricultural diseases are also opportunistic diseases. These disease agents are usually food or waterborne diseases that can pose a significant health risk due to the ease of their entry into the food and water supply. Agroterrorism disease threats are those that may infect the industries of livestock or agriculture but the potential can expand to include the food and waterborne disease. For these reasons they have been categorized as agricultural diseases of significance.

Emerging Infectious Disease—These diseases are defined as those that have newly appeared within a given population, are showing increased incidence within a population or are expanding their geographic range. Many emerging diseases are vector borne diseases. Vectors are often highly influenced by climate factors and can increase geographic range and introduce emerging diseases to new hosts. Table 2 lists many current diseases of significance within the US. Zika has gained a lot of attention lately as a disease that causes high morbidity in developing human fetuses. Ebola is another emerging disease, not transmitted by a vector, which caused global panic in 2013. The US government has spent over $1.3 billion in preparing for the potential spread of the African Ebola epidemic to US shores.[48] There were 45 hospitals in the US identified as potential Ebola treatment centers. These centers spent an average of $1 million initially to prepare their centers to be able to treat potential infections.[49]

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[48] Office of the Press Secretary, "Fact Sheet: The U.S. Government's Response to Ebola at Home and Abroad," The White House, October 22, 2014, accessed January 22, 2016, https://www.whitehouse.gov/the-press-office/2014/10/22/fact-sheet-us-government-s-response-ebola-home-and-abroad.

[49] J. J. Mark Haverkort et al., "Hospital Preparations for Viral Hemorrhagic Fever Patients and Experience Gained from Admission of an Ebola Patient," *Emerging Infectious Diseases* 22, no. 2 (February 2016): 184-191.

Vaccine Preventable Infectious Disease—These illnesses are caused by organisms for which reliable and safe vaccines exist. Before the US vaccination campaign began, the mortality rate for children from infectious diseases was staggering at 12,500 per year.[50] Since the introduction of vaccines the public health community has significantly reduced the overall mortality in children of these diseases. In the current era of medicine, vaccines have greatly reduced or eliminated the occurrences of preventable disease. Diseases such as Polio, Measles, Mumps, Rubella, Smallpox, and Hepatitis have all been significantly reduced do to the introduction of vaccines.[51] Smallpox was officially eradicated globally in 1980[52], the only disease able to carry that moniker, while Measles was nearly considered eradicated in the US by 2000.

Influenza is an endemic communicable disease that kills 3,000 and 49,000 US citizens each year.[53] The total cost burden of influenza to the US is $87.1 billion.[54] Influenza will be categorized as a vaccine preventable disease. Vaccines for influenza are developed annually to combat what the most anticipated strains will be present in a particular year. The vaccine is not common to all strains of influenza.

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[50] Cynthia G. Whitney et al., "Benefits from Immunization during the Vaccines for Children Program Era-United States, 1994-2013," *Morbidity and Mortality Weekly Report (MMWR)* 63, no. 16 (April 2014): 352-355.

[51] Ibid., 352-355.

[52] The Center for Food Security and Public Health, "Smallpox" (Information Report, College of Veterinary Medicine Iowa State University, Ames, 2004).

[53] Levi et al.

[54] Ibid.

Opportunistic Infectious Disease—Opportunistic diseases exploit favorable conditions in order to promulgate and may have some overlap with the other categories of disease threats listed in this research. In order to eliminate the difficulty in categorizing opportunistic disease the definition for this paper will limit the opportunistic disease category to those that have become resistant to medications used to treat them or diseases that are acquired in a hospital setting. The Robert Wood Johnson Foundation estimates the impact of these diseases to be $55 billion annually which includes direct and indirect costs.[55] The monetary figure shows that opportunistic diseases place a large and direct financial burden upon healthcare costs. These threats have originated from within the healthcare system from the over prescribing of antibiotics or from hospital decontamination practices.[56]

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[55] Scott.

[56] Mitchell L. Cohen, "Changing Patterns of Infectious Disease," *Nature* 406 (August 2000): 762-767.

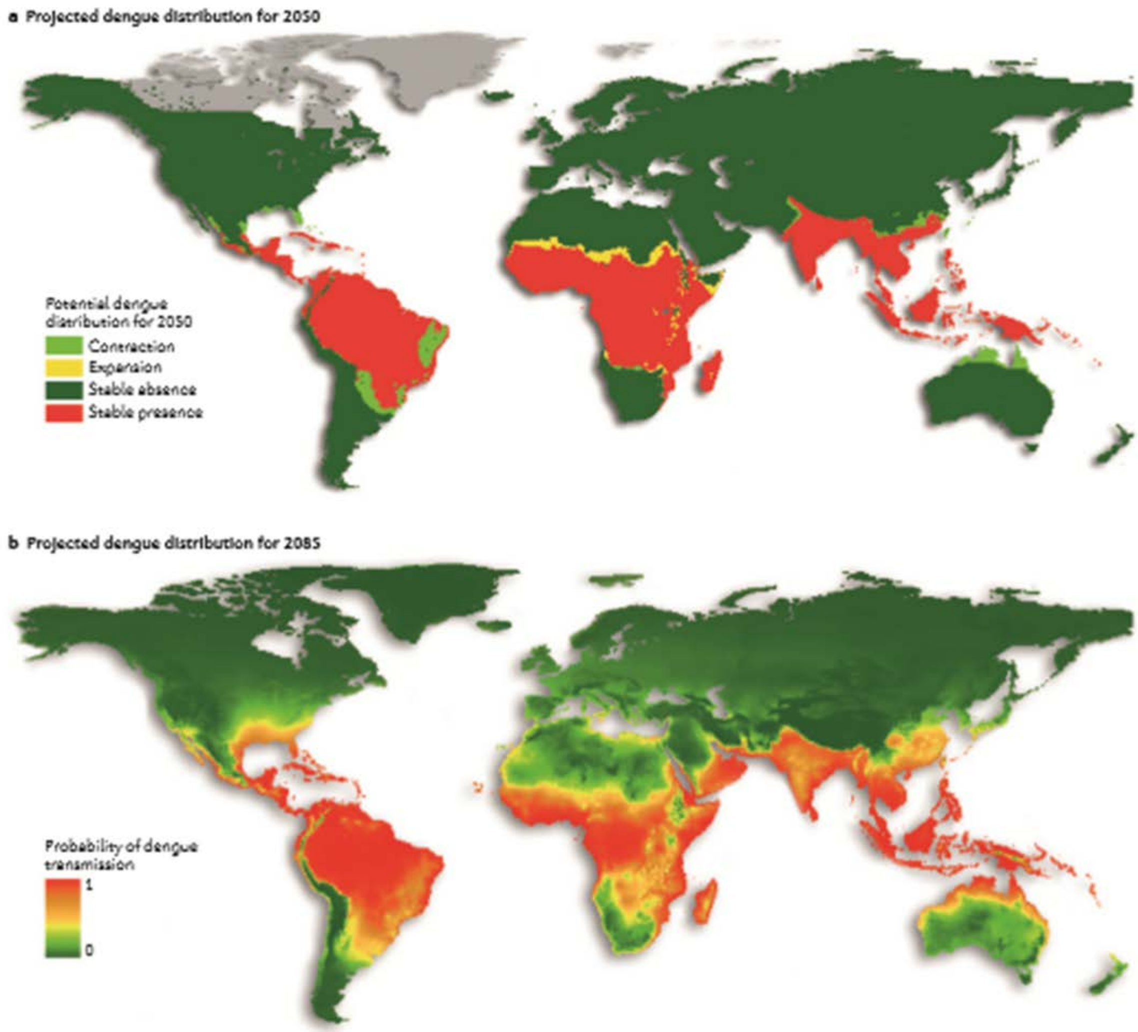

Figure 3. Dengue Projected Spread due to Climate Change by 2050 and 2085

Source: Jane P. Messina et al., “The Many Projected Futures of Dengue,” *Nature Reviews Microbiology* 13 (2015): 230-239.

Note: This figure uses a statistical model to display the potential and projected occurrence of Dengue based on range of vector and social factors. This model can theoretically be used for many vector borne diseases that are dependent on climate change models.

Dengue is a vector born disease that uses mosquitoes as a vector to bite and infect a host. The particular genus of mosquito that transmits Dengue is the *Aedes* and its range of habitat is highly dependent on climate change.[57] This figure shows the potential range for the spread of Dengue due to the increased range of habitat of the vector. As global surface temperatures continue to increase due to climate change factors, so too will the vector habitat increase away from the equator.[58] The disease and vector are currently found in the southern portion of the US, but cases have been identified as far north as Ohio and Indiana.[59]

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[57] David M. Morens and Anthony S. Fauci. "Dengue and Hemorrhagic Fever: A Potential Threat to Public Health in the United States," *JAMA* 299, no. 2 (January 2008): 214-216.

[58] Levi et al.

[59] Morens, 214-216.

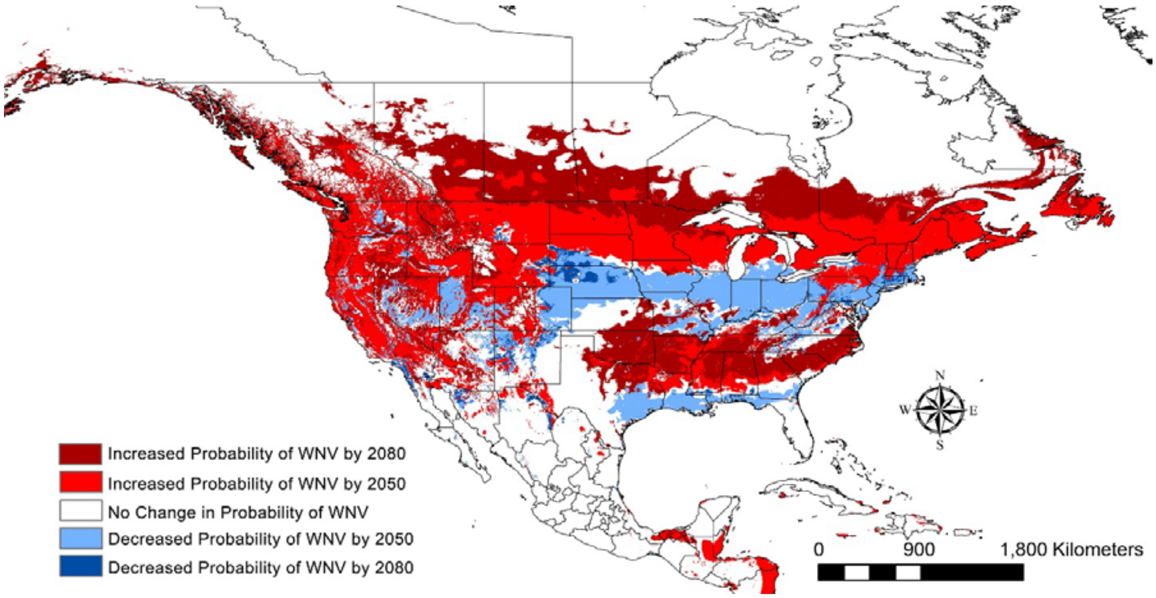

Figure 4. West Nile Virus Projected Spread due to Climate Change by 2050 and 2080

Source: Ryan J. Harrigan, Henri A. Thomassen, Wolfgang Buermann, and Thomas B. Smith, "A Continental Risk Assessment of West Nile Virus under Climate Change," *Global Change Biology* 20, no. 8 (August 2014): 2417-2425, doi:10.1111/gcb.12534.

Note: Research out of UCLA models the spread of West Nile virus by 2050 and 2080 as a result of climate change. Red indicates increased probability of the virus. Blue indicates decreased probability.

West Nile Virus (WNV) is similar to Dengue in that the vector, in this case the mosquito genus is *Culex*, is also highly susceptible to climate change patterns. There are multiple similarities in the dispersion patterns of this particular species of mosquito compared with the *Aedes*. They both thrive in warmer, more humid climates. The two genera of mosquitoes do have differences in breeding and reproductive patterns that pose unique challenges to public health efforts to control them.

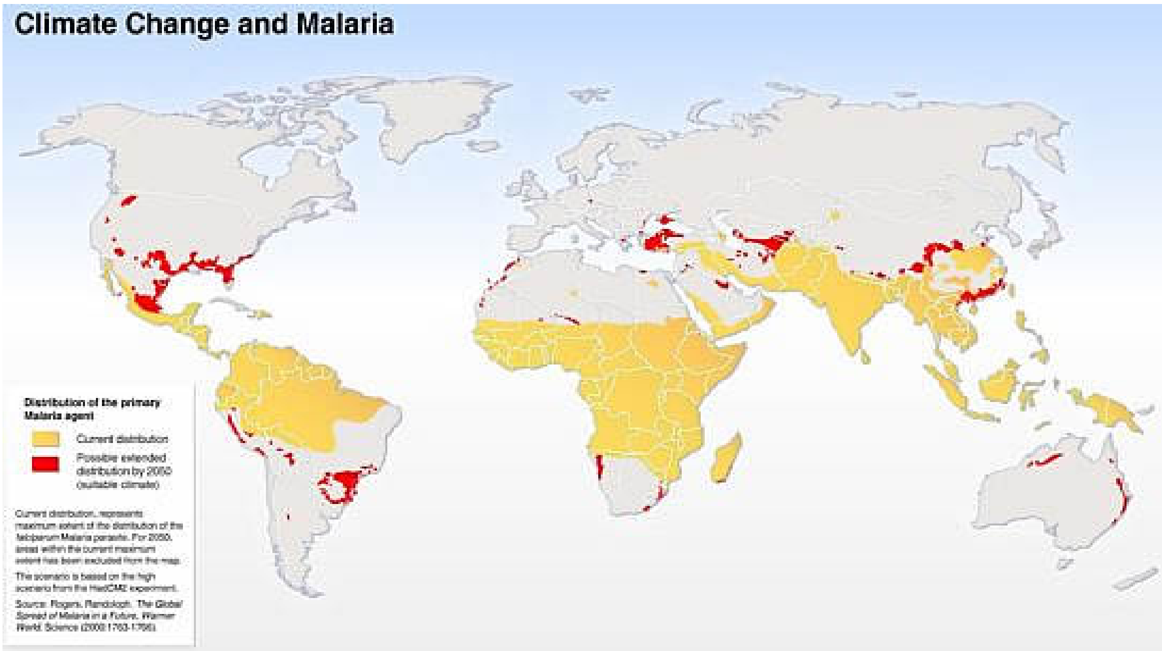

Figure 5. Malaria Projected Spread due to Climate Change by 2050

Source: Center for Science Education, “Climate Change and Vector-Borne Disease,” Figure courtesy of Hugo Ahlenius, UNEP/GRID-Arendal, accessed February 11, 2016, http://scied.ucar.edu/longcontent/climate-change-and-vector-borne-disease.

Note: Climate change will allow Malaria to spread into new areas. This map shows the new areas where the Malaria parasite, will likely be able to spread by 2050 based on the Hadley Centre model’s high scenario. Areas shown in yellow indicate the current distribution of Malaria. Areas shown in red indicate areas where climate will be suitable for Malaria by 2050. Other areas may become free of Malaria as climate changes.

According to the latest WHO estimates, released in December 2015, there were 214 million cases of Malaria in 2015 and 438,000 deaths globally.[60] The disease vector is the *anopheles* mosquito. Through extensive use of pesticide and habitat reformation, Malaria was all but eliminated from the US through the control of the mosquito

[60] World Health Organization, *World Malaria Report 2015* (Geneva: WHO Library Cataloguing-in-Publication Data, 2015).

population. Most new cases of Malaria in the US come from international travelers returning to the US. Many of the pesticides used to control the vector population are no longer legal for use in the US. As a result, the vector population has increased dramatically, yet the reintroduction of Malaria into the population of vectors in the US has not occurred. If enough population of persons residing in the US were to be infected with Malaria, the potential for Malaria to reenter the population would exist.

Challenges

One challenge is the ability to ascertain the nature of bioterrorist threats from international state actors. These programs are often veiled in secrecy as international treaties against the proliferation of bioweapons have been enacted. The former Soviet Union actively produced biological agents for war. They created super virulent and hardy strains of both smallpox and anthrax. The extent of the Soviet anthrax program was unknown to the US until an accident occurred at a Soviet bioweapons research facility. Anthrax spores were accidentally released into a neighboring village which ultimately caused deaths from inhalation anthrax to many of the inhabitants.[61]

Conclusion

The data presented suggests that there exists a large threat to the population of the US in terms of direct threat to the health and well-being of the public and to the economy. Huge amounts of time, effort and funding have been applied to threats posed by infectious disease agents. A significant amount of government funding has gone into addressing the emergence and detection aspects of biosecurity. The US maintains a

[61] Inglesby et al., 1735-1745.

robust disease surveillance network that has significant capability to identify outbreaks quickly, yet in a disease that incites public fear such as Ebola, the emergence and detection may not be enough.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

The significance of this study is that it will help to identify potential gaps in the current response strategy towards infectious disease. There has been a significant amount of research conducted with regards to all aspects of infectious disease. From the effects of climate change on diseases and disease vectors, to the potential effects of the introduction of an opportunistic disease organism into the agricultural industry much science and data has been developed.

Emergency response plans have been created based on these studies, but there is much work that can be done. The CDC gave the US population a false sense of security in 2014. They said Ebola would not reach US shores because the surveillance and response measures in place in West Africa were effective, yet weeks later an Ebola infected man visited an emergency room and infected two healthcare workers. These incidents illustrate there are challenges in the preparedness and response systems.

Emergency response plans have been created at the recommendation of these studies. But there is much work that can be done. The CDC had given the US population a false sense of security in 2014 when they said Ebola would not reach US shores because the surveillance and response measures in place in West Africa were effective. Weeks later an Ebola infected man visited an emergency room and infected two healthcare workers. This incident highlights challenges to preparedness and response systems.

Another example of a preparedness gap is measles, a vaccine-preventable disease, considered eliminated in the US in 2000, yet in 2015, there were multiple outbreaks of the disease in the US.[62] The common denominator in the measles outbreaks was that the majority of those infected were unvaccinated individuals. This is a gap in state policy that threatens US biosecurity efforts.

Operational Approach

This study will gather relevant data across to identify gaps in the assessment of threats to the biosecurity of the US. Many of these gaps may be influenced by one or a number of variables such as climate, global human movement, climate change and a susceptible population. A secondary goal of this study is to identify controls or mitigation factors or identify a need for further research to develop them.

Research Methodology

This research will utilize case studies as a means to identify potential variables and threats from disease. An analysis of the case studies will identify potential effects of climate change and globalization on the range of infectious disease. A great deal of the information presented in the case studies is derived from quantitative studies. Mosquito ranges are based on research conducted that incorporates weather, terrain, temperature, transmissibility of the infectious organisms, and vector's reproductive ability at various temperatures. Globalization research methods being evaluated come from quantitative and qualitative studies that identify reasons for human migration. These studies have

[62] Headquarters, Department of the Army, Army Techniques Publication (ATP) 5-19, *Risk Management* (Washington, DC: Department of the Army, 2014).

looked at global strife and economic challenges as potential reasons that drive migration. In the US, the Department of Homeland Security presents general findings of research conducted from apprehended illegal and unauthorized immigrants.[63]

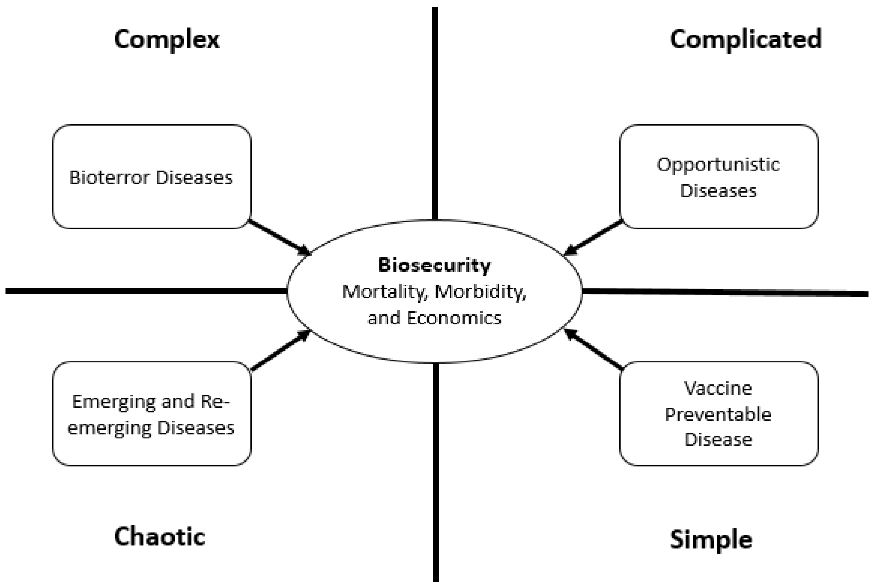

Figure 6. Infections Disease Problem Solving Method

Source: Created by author.

Note: Displays the categories of infectious disease against an interpretation of the Cynefin Framework (a civilian model for describing complex problems). The result is a four quadrant model that categorizes the threat from infectious disease and the type of problem that can be expected.

A civilian organizational approach for identifying and framing complex problems uses the Cynefin Framework.[64] The Cynefin Framework was created by Harvard

[63] Lead Shaun Pang, "Biosecurity: Addressing the Threat of Bioterrorism and Infectious Disease" (Master's Thesis, United States Marine Corps Command and Staff College, Quantico, VA, 2010).

University researchers. It is a means to show the balance between problems that can border between order and disorder or vary in complexity. It places most problems into one of four quadrants which are complex, complicated, chaotic and simple. Simple and complicated problems can be framed much more easily than can complex or chaotic problems. Simple and complicated problems lean on the ordered problems to be solved. Enough is known about them that they are either easily solved or because it is easy to identify the mitigation measures required to solve them. Complex and chaotic problems are not as easily solved. Chaotic problems have many unknown variables that make it difficult to assign the proper resources. Complicated problems may require a multilayered approach or may be difficult to identify common variables that could then be exploited in either a good or bad manner.

Figure 6 is a synopsis of the combination of the infectious disease categories presented during this research against the Cynefin Framework. Placing disease categories into one of these quadrants was achieved by assessing the disease variables that identified the complexities and difficulties in identifying control measures. This categorization is used to identify diseases to serve as the case studies. Figure 6 shows that the most difficult problems are those presented by emerging, reemerging, and bioterror disease threats. Since these threats can play off of a multiple of unknowns and variability, there categorization into a chaotic and complex environment seems most suitable. Opportunistic and vaccine preventable diseases do not have the same amount of unknowns. Many of these diseases have mitigation strategies identified that control the

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[64] David J. Snowden and Mary E. Boone, "A Leader's Framework for Decision Making," *Harvard Business Review*, November 2007, accessed April 26, 2016, https://hbr.org/2007/11/a-leaders-framework-for-decision-making.

magnitude of outbreaks within the US. This categorization is hypothetical but will be used to identify the case studies to show relevancy. What figure 6 is visually representing is that the most difficult problem sets are those presented by emerging, reemerging, and bioterror disease threats. Since these threats are variable they are categorized as chaotic and complex. Opportunistic and vaccine preventable diseases do not present with the same amount of unknowns. Many of these disease organisms have mitigation strategies identified that control the magnitude of outbreaks within the US.

Case studies were selected from each disease category listed in figure 6. Data exists that encompasses the response to recent outbreaks of Ebola and Zika. These are two recent examples of emerging and reemerging diseases that have caused public panic and have been identified by the WHO as disease outbreaks of public concern. Much is known about Ebola. There have been local outbreaks in Africa of Ebola, and due to its mortality rates in infected populations, it was quickly determined a disease of global concern. Zika, at the time of this study, is still relatively unknown. Zika was identified over 50 years ago, yet only recently has significantly impacted the public health of people.

Vaccine-preventable and opportunistic diseases have multiple, long-term studies, that show effects and consequences of the current vaccine policy in the US. Much of the information provided for response measures are longitudinal or ongoing in nature. Vaccination research, morbidity and mortality rates have been recorded for the greater portion of the millennium and can provide a great source for trend analysis, vital to identifying and assessing risk from infectious disease.

After the anthrax letter events of 2001, much focus and research has been with addressing bioterrorism. A vulnerability that has been identified is an attack upon the agricultural sector of the US, referred to as agroterrorism. Data has shown that these events, although rare, can inflict public panic or consume significant resources to address, mitigate and respond to. The potential agents used in these attacks have a vast amount of data that show estimated mortality rates and economic impacts to communities.

<u>Variables</u>

We can identify the variables associated with infectious disease and describe the inter-relationships between them. Showing nodes that are interconnected begins to explain some of the intricacies of the environment for which you are operating within.

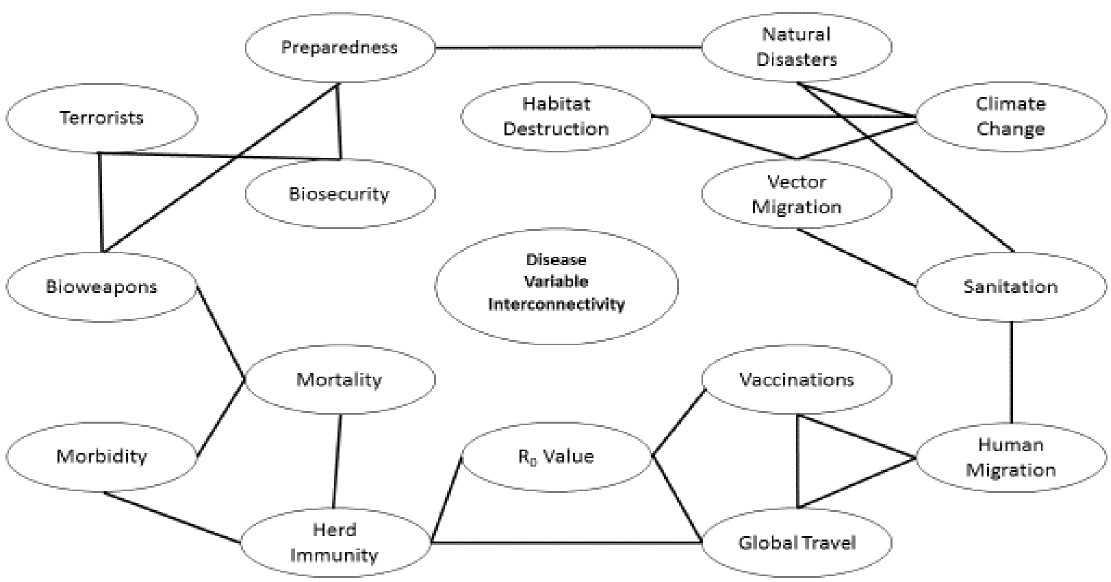

Figure 7. Infectious Disease Variables and Interconnectivity

Source: Created by author.
Note: Shows the interconnectivity of identified infectious disease variables. This figure highlights the difficulty in narrowing the focus of preparedness and response plans. Many of the variables identified are not specific to one category of disease.

From figure 7 above, we can describe some potential nodes common to this threat that can be exploited. Climate change and the global movement of people interact with the most variables. This would mean that efforts aimed at understanding these variables (intelligence collection) might aid in the identification of some objectives (ends) that could then have resources allocated to manage them (means). The desired end states are the conditions that must be met in order for the mission to be complete. Getting from the current state to an end state requires the development of a problem statement in order to identify an approach that will allow the movement from one state to the other. Figure 7 shows some of the problems that must be addressed to reach a desired of mitigating the risks of biosecurity threats. Studying the interaction between the variables and identify an end state, risk reduction measures could be enacted to break the linkages. Some linkages can also serve as opportunities. The linkage between public preparedness and climate change can help to identify some approaches the public sector can take to prepare for potential disease outbreaks.

Evaluation Criteria

The evaluation criteria used in this study will focus on a diseases ability to cause high mortality—morbidity in the population against the likelihood of the disease to occur within the US. The US Army uses a process called Composite Risk Management to identify and control hazards that may affect a mission outcome.[65] "Unidentified and unmanaged hazards and their associated risks impede successful Army missions, undermine readiness, decrease morale, and deplete resources. The holistic approach of

[65] Headquarters, Department of the Army, ATP 5-19.

risk management provides commanders a tool to recognize, evaluate, eliminate, and control the diverse threats and risks to mission execution." Identified risks are then categorized and charted based on the severity of the risk and the probability of the risk occurring. This paper will utilize the US Army Risk Assessment Matrix as a template to evaluate the morbidity—mortality (Severity) and the likelihood of the disease occurring (Probability) to identify the overall risk of an organism to the US population. The existing risk matrix has been modified to the relevancy of measuring disease variables that could be used to quickly assess the risk of an infectious disease outbreak.

The WHO uses a similar risk assessment tool to identify the potential risks of a public health event. If an event is of significant magnitude it can be labeled a "public health emergency of international concern (PHEIC)."[66] A PHEIC is defined in the International Health Regulations as "an extraordinary event which is determined to constitute a public health risk to other States through the international spread of disease and to potentially require a coordinated international response."[67] There are three criteria that must be met to make this distinction. The event has to be serious, sudden, unusual or unexpected; and must carry implications for public health beyond the affected State's national border; and-may require immediate international action.[68] The WHO Director-General will seek the council of the International Health Regulation Emergency

[66] World Health Organization, *Rapid Risk Assessment of Acute Public Health Events* (Geneva: WHO Press, 2012).

[67] Director-General, *Implementation of the International Health Regulations (2005): Responding to Public Health Emergencies* (Geneva: World Health Organization, 2015).

[68] Ibid.

Committee to make the final determination and issue preliminary guidance for any response.

The Rapid Risk Assessment of Acute Public Health Events is an all-hazards tool supported by the WHO to assist national public health departments to assess a public health crisis to determine if the crisis has the potential of becoming a PHEIC.[69] The tool places the estimate of likelihood on one axis against the estimates of consequences. The tool is quantifiable describing likelihood, using percentages of probability that an event is likely to occur. The tool is subjective when describing the estimates of consequences, using words such as limited, minor, severe, and serious to describe the magnitude of effects.

[69] World Health Organization, *Rapid Risk Assessment of Acute Public Health Events*.

Table 3. Infectious Disease Threat Matrix

INFECTIOUS DISEASE THREAT MATRIX

Biosecurity Threat Levels
EH-Extremely High (National and International Response)
H-High (Full State Response with National Support)
M-Moderate (County Response with State and National Support)
L-Low (Local and County Level Response)

SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US (Varaibles are #Vectors, # people (globalization), susceptibility of population) →	INEVITABLE Probability of Occuring 90%-100%	LIKELY Probability of Occuring 70%-90%	OCCASSIONAL Probability of Occuring 30%-69%	SELDOM Probability of Occuring 10%-29%	UNLIKELY Probability of Occuring <10%
	CATASTROPHIC Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Headquarters, Department of the Army, Army Techniques Publication (ATP) 5-19, *Risk Management* (Washington, DC: Department of the Army, 2014), 1-7.

Note: Infectious Disease Threat Matrix adopted from the US Army Composite Risk Management hazards matrix. It has been altered to be of practical use in identifying the threat associated with an infectious disease. The axis will quantify the probability of a disease occurring in the US with the severity of the resultant outbreak to provide an overall biosecurity threat level.

The Infectious Disease Threat Matrix (IDTM) (table 3) measures the overall biosecurity threat to the US as a product of comparing the likelihood of an outbreak with the severity of the outbreak. The biosecurity threat levels are defined as extremely high, high, moderate and low. The biosecurity threat level also mentions the all-hazards response that an outbreak would require. A biosecurity event labeled as extremely high (EH) would most likely require a national response and has the potential for also requiring a congruent international response.

The probability of a disease outbreak to occur is dependent on variables such as vectors, people migration, and susceptibility of a population. Globalization and climate change have the potential to increase the probability of an event occurring. As more vectors, international travelers and immigrants cross into the US and meet a susceptible population, the chances of outbreaks to occur grow. Some diseases are more prone to these effects than others. This model can provide an overview of disease categories but is more suited to be used in assessing individual diseases or outbreaks.

In the IDTM, the categories for “probability of an outbreak occurring” are inevitable, likely, occasional, seldom and unlikely. These categories have a percentage associated based on an assessment of variables that can influence an outbreak. A disease that is transmitted via a vector is influenced by climate. As the climate changes so do the ranges of many vectors. As climate change models have shown in chapter 2, the potential spread of many vectors of disease will place a larger portion of Americans at risk. A disease that is dependent on human to human transmission may be influenced by globalization. Migration and global travel increase the likelihood of contact with many diseases and serve to spread virulent diseases, such as the flu, more easily.

The severity of an outbreak also has multiple variables to help ascertain a magnitude of effect. In the IDTM, the categories for “severity of an outbreak” are catastrophic, critical, marginal and negligible. The severity variables can be assessed either individually or can be assessed as a group. An ability of a disease to cause significant mortality is of concern, but so too is the disease’s ability to cause significant economic impact. Although one is not higher in importance, this infectious disease threat matrix serves as a neutral means to identify the risk of an associated outbreak.

Disease agents that fall within the Extremely High (EH) category will elicit a greater fear response within the general public and can be a source for public panic. Historical examples of disease agents within this category include smallpox and Ebola. Along with the potential for producing the most harm, the virulence of the organism to infect a susceptible population is at focus. In a population of children and adults who are not immunized against vaccine preventable diseases, the threats of communicable disease increase, and therefore cause unnecessary strain on the public health entities in place to combat them. A disease endemic to a population may occur at a much higher frequency regardless of severity. One example of this type of organism is the flu virus, which infects hundreds of thousands Americans each year but whose fatality rate varies but overall has been relatively low.

For this study, Severity will also consider an economic impact of the disease on the economy. Effects upon the economy may vary in magnitude and will include direct and indirect costs associated with combating the organisms or their effects. For instance, if an agent of agricultural significance such as “hoof and mouth disease” were introduced into the livestock, a potential response measure would be to destroy all cows within the farm, could include neighboring farms and eventually could lead to policies against the exportation of US beef products. This economic outcome would rate high on the economic severity spectrum and thus would have to be considered along with morbidity and mortality of a population.

The case studies chosen for analysis categorically represent multiple diseases that may or may not have the same mechanisms for producing outbreaks. The cases studies chosen also represent a majority of disease that have sparked some public interest and the names of disease which still can be identified in some way by the general public. The six case studies that will be discussed in chapter 4 are anthrax, measles, Zika, Ebola, salmonella and hospital acquired infections. A risk assessment of these diseases will be produced.

Threats to Validity and Biases

The validity of this study is a product of interpretation as to the scope and magnitude of a disease outbreak when framed as the probability of the outbreak occurring and the severity of the outbreak. This interpretation is subjective but based off of empirical data that has been gained by public health officials for multiple decades. Assessing risk in general may be subjective but using quantitative data and facts will serve to eliminate much of the subjectivity.

Data exists that highlight the social media aspect of combating infectious disease. Vaccine-preventable infectious diseases have been combated by a growing subpopulation, that have been associated the disease with autism. To public health officials this stance is further from the truth than many chose to believe. It is hard to change the potential bias of some thru a study like this. To truly get at the social aspect of how people perceive disease and outbreak would need to be analyzed to full gain understanding. The bias of the media can influence the degree to which the general public may approach outbreaks of disease.

Conclusion

The data and demographics presented in chapter 2 shed light on the potential for identifying gaps that this study seeks to fill. The amount of resources being invested has three potential capabilities to address. Does money get spent researching the emergence of diseases by studying the disease agent itself or increasing the surveillance capacity of countries without robust surveillance systems? Or should money be spent on detection and laboratory capacity here in the US mainland to be able to identify outbreaks before they gain a stronghold in the population? Or should resources be improved in the overall response to disease when they occur? The three lines of effort, emergence, detection and response are the framework for the national strategy for biosecurity.

CHAPTER 4

ANALYSIS

Introduction

Chapter 4 will expand the lens of assessing risk to the population from disease organisms in the categories of bioterrorism, vaccine preventable, opportunistic, emerging and reemerging disease. The six case studies, (anthrax, salmonella, measles, Zika, Ebola and hospital acquired infections) were chosen because they are the most current to the general public and are still representative of the four disease categories. A risk assessment of these diseases will be produced. The guiding question that this paper seeks to answer is: how do we assess the threat of infectious disease organisms given the effects of climate change, human migration, global travel, and a population of unvaccinated persons?

Research Purpose

The purpose of this study is to evaluate the threat of infectious disease to the biosecurity of the US population with respect to climate change, globalization, human migration and unvaccinated populations. This study will seek to identify gaps in biosecurity. The gaps identified could identify needs for further research, potential mitigation strategies, and provide for an overall risk assessment of a disease to a given population.

Ebola

There have been more than 20 Ebola outbreaks since the disease was first described in 1976. The one that began two years ago in West Africa was by far the worst, and it was the first to reach the US. The West African Ebola outbreak, which has claimed more than 11,000 lives, has several times come close to being declared over, but a dozen new cases recently appeared in Liberia and Guinea. The overall mortality rate for Ebola ranges from 40 percent in the most recent outbreak to 100 percent in previous outbreaks.[70] Ebola caused a panic in the US which forced the healthcare industry and the US government to prepare costly preparedness and response plans.

Table 4. IDTM for Ebola

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels **EH**-Extremely High (National and International Response) **H**-High (Full State Response with National Support) **M**-Moderate (County Response with State and National Support) **L**-Low (Local and County Level Response)		**PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US** (Varaibles are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	**LIKELY** Probability of Occuring 70%-90%	**OCCASSIONAL** Probability of Occuring 30%-69%	**SELDOM** Probability of Occuring 10%-29%	**UNLIKELY** Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	**CATASTROPHIC** Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

The probability of an emerging or reemerging infectious disease to reach the US is inevitable. In the case of Ebola the host is not endemic to the US and therefore an outbreak within the US would most likely originate in Africa. These diseases have shown

[70] Centers for Disease Control and Prevention, "Cases of Ebola Diagnosed in the United States," December 16, 2014, accessed May 25, 2016, http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/united-states-imported-case.html.

a remarkable ability to cross borders into susceptible populations. For those reasons the likelihood of Ebola occurring in the US has been changed to occasional (table 4).

The response to Ebola was global in magnitude. The recent outbreak affected trade and travel for the persons or goods originating in West Africa. The current outbreak of Ebola still had a very high mortality rate compared to other viruses. For those reasons Ebola has been given a severity rating of catastrophic (see table 4).

Zika

As of the writing of this paper, the current threat from emerging diseases comes from the Zika virus. This virus has been identified for over 50 years, yet within the last two years has exploded on the world scene. "On February 1st, 2016, based on recommendations of the International Health Regulations Emergency Committee, WHO declared the increasing cases of neonatal and neurological disorders, amid the growing Zika outbreak in the Americas, a Public Health Emergency of International Concern which launched the global Strategic Response Framework and Joint Operations Plan to guide the international response to the spread of Zika virus infection and the neonatal malformations and neurological conditions associated with it."[71]

The Zika virus has been correlated with the rising numbers of children born with microcephaly in Brazil. Although the mechanisms have yet to be determined, the virus

[71] World Health Organization,"WHO Director-General Summarizes the Outcome of the Emergency Committee Regarding Clusters of Microcephaly and Guillain-Barré Syndrome," February 1, 2016, accessed May 23, 2016, http://www.who.int/ mediacentre/news/statements/2016/emergency-committee-zika-microcephaly/en/.

seems to attack a developing fetus inside the womb of a pregnant individual.[72] The uniqueness of this virus is that it was only thought to have spread through a mosquito vector host, but now has been proven to also be transmitted through sexual intercourse.

In the US there are now 672 people infected with Zika, 64 of them pregnant women who are considered the most at risk. The infection has been linked to birth defects and brain damage in infants born to infected mothers, and to paralysis in adults. About half of those cases involved local transmission within Puerto Rico, the US Virgin Islands and American Samoa.[73] Almost all the remainder occurred in travelers who returned from countries where the Zika epidemic was raging.

Since the Zika virus is both vector transmitted and sexually transmitted, public health measures to prevent the spread of the disease are significantly complicated. The first confirmed case of Zika being transmitted sexually occurred in Dallas, Texas, when a man who had returned from an overseas destination infected a female after having a sexual encounter. Prevention measures are difficult because public health officials have to consider measures to both prevent sexual disease through condom use and to find ways to prevent the transmission from mosquitoes.

The mosquitoes that transmit Zika are from the *Aedes* genus, mainly *Aede*s *aegypti* in tropical regions. This mosquito also transmits Dengue, Chikungunya, and Yellow Fever. The difficulty in controlling mosquitoes is that their habitats and breeding

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[72] Lavinia Schuler-Faccini et al., "Possible Association Between Zika Infection and Microcephaly-Brazil, 2015," *Morbidity and Mortality Weekly Report* (*MMWR)* 65, no. 3 (January 2016): 59-62.

[73] Centers for Disease Control and Prevention, "Zika Virus—Transmission and Risks," May 12, 2016, accessed May 14, 2016, http://www.cdc.gov/zika/transmission/index.html.

cycles are conducive in a tropical environment. The *Aedes* and *Anophele*s genus of mosquitoes thrive in varying habitat to include running or standing water, open containers and standing pools of water, and both urban and rural settings. These mosquitoes thrive in any environment with the right temperature and humidity.

Table 5. IDTM for Zika

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels **EH**-Extremely High (National and International Response) **H**-High (Full State Response with National Support) **M**-Moderate (County Response with State and National Support) **L**-Low (Local and County Level Response)		**PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US** (Varaibles are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	**LIKELY** Probability of Occuring 70%-90%	**OCCASSIONAL** Probability of Occuring 30%-69%	**SELDOM** Probability of Occuring 10%-29%	**UNLIKELY** Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	**CATASTROPHIC** Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

The probability of a Zika outbreak in the US is currently occasional. What makes Zika dangerous to the US is that it is transmitted via unprotected sexual intercourse and through the bite of an infected mosquito. As more people become infected and with mosquito populations increasing their ranges due to climate change, the likelihood of a Zika outbreak occurring in the US will increase dramatically (to likely or inevitable) on the IDTM (see table 5). The other unknown with Zika is that current research is still seeking answers to how the disease changed to be a public health issue in people only recently. Whether that change occurred as a reason of a mutation of the virus, a change in vector patterns, or a change in human social interactions, the true magnitude of threat posed by Zika is still not known. The risk assessment places the effects of a Zika outbreak as critical (table 5) due to the high morbidity placed on developing human fetuses and the relative ease of spread of the virus.

Anthrax

In September and October of 2001, letters containing Anthrax spores were deliberately sent through the United States Postal System to various public officials. In all, 22 cases of Anthrax were reported and 6 people died from the organism. This was one of the worst bioterror attacks against the US.

The total cost of response to the Anthrax bioterror attack was over $3 billion.[74] This figure includes the decontamination costs of the US Postal facilities that were affected, the buildings of the United States Congress, the American Media Inc. building, and the prophylaxis treatment of over 33,000 people who may have been exposed to the Anthrax contaminated letters.

To highlight how potential virulence of a bioweapon we could look at the former Union of Soviet Socialist Republics. In 1979 an anthrax epidemic occurred in Sverdlovsk, of the former Union of Soviet Socialist Republics. A soviet bioweapons research facility accidentally released roughly a gram of weaponized inhalation anthrax.

[74] David Heyman, *Lessons from the Anthrax Attacks Implications for U.S. Bioterrorism Preparedness* (Washington, DC: Center for Strategic and International Studies and the Defense Threat Reduction Agency, 2002).

A maintenance worker in the facility did not install a vent filter correctly allowing for the accidental release of the spores to the neighboring community. Approximately 96 cases of Anthrax were reported resulting in 64 deaths.[75] The incubation period for this outbreak was four to 46 days in length, which highlights one of the potential risk factors with a bioweapon attack.[76] The incubation period of a disease is the time from which an individual comes in contact with an organism before they show signs and symptoms of the disease manifestation. It is during this time that many disease pathogens can be spread from one individual to another and often times the individuals are unaware of their infection.

Table 6. IDTM for Anthrax

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels EH-Extremely High (National and International Response) H-High (Full State Response with National Support) M-Moderate (County Response with State and National Support) L-Low (Local and County level Response)		PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US (Variables are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	LIKELY Probability of Occuring 70%-89%	OCCASSIONAL Probability of Occuring 30%-69%	SELDOM Probability of Occuring 10%-29%	UNLIKELY Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	CATASTROPHIC Mortality: >50% Transmisability R_0: >7 Economic: Will result in Trade/Travel Restrictions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmisability R_0: >5 Economic: Might result in Trade/Travel Restrictions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmisability R_0: >3 Economic: Likely local response sufficient Treatment: readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmisability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

[75] Matthew Meselson et al., "The Sverdlovsk Anthrax Outbreak of 1979," *Science* 266 (1994): 1202-1208.

[76] The Center for Food Security and Public Health, "Anthrax."

The world has seen the effects of what a bioterrorist attack using Anthrax on a population would look like. Anthrax spores can survive dormant for hundreds of years which makes cleanup a costly response effort as seen with the US Anthrax letter attack. Inhalation anthrax, the type most likely to be used by a terrorist, produces high mortality in those infected. These two variables place the severity of an outbreak into the catastrophic rating (table 6). Anthrax is not transmitted person to person, so an outbreak would be contained to the infected area. It is nearly impossible to predict the likelihood of an attack on the US, so we must plan as if an attack will occur again. An Anthrax attack is given a seldom probability of occurring in the US according to the IDTM (table 6).

Salmonella

In 1980, a religious cult in Oregon, followers of Bhagwan Shree Rajneeshee, were seeking seats in the local government. Many locals in the area were opposed of the potential of the religious followers gaining seats in the local government. The cult leader, Rajneeshee, decided that the only option was to limit the opposition in the election. He ordered his followers to taint local restaurant salad bars with Salmonella. A total of 10 restaurants were attacked and 750 cases of Salmonella were reported in a town of 10,000 residents.[77] This would prove to be the largest bioterror—agroterrorism incident on US soil. There were no deaths as a result of the attack.

An attack on the food source of a population such as the Rajneeshee attack is difficult to prevent. A 29-year-old man was arrested in Michigan after being caught on surveillance camera contaminating grocery store salad bars with rat poison. Although an

[77] Texas Department of State Health Services.

infectious disease agent was not used in this attack, it serves as an example of how vulnerable smaller populations would be against this type of terror attack and the manner of which it was carried out was similar to the Oregon attack. It is still unknown how many grocery stores were affected but it is believed to be 15.[78] The suspect did not have ties to terrorist organizations but this incident highlights the potential threat that bio and agro terrorism can pose to the US population.

Though not classified by the CDC or WHO as a potential bioterrorist threat, salmonella's use as bioweapon highlights the complexities of classifying what disease agents are considered bioterror agents. For this study Ebola was placed in the emerging and reemerging category of infectious diseases. In a video teleconference to Army Medical Department students at the United States Army Command and General Staff College, the United States Army Surgeon General, Lieutenant General Nadia West, offered that organisms such as Ebola could be used as bioweapons. The United States Army Surgeon General stated that "terrorists could use Ebola patients as suicide bombers," and coupled with how Ebola is transmitted, could potentially have a more lingering effect.

[78] Joshua Berlinger, "Man Sprayed Poison on Open Food at Grocery Stores, FBI Says," *CNN*, May 5, 2016, accessed May 24, 2016, http://www.cnn.com/2016/05/05/health/michigan-food-contamination-poison/.

Table 7. IDTM for Salmonella

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels **EH**-Extremely High (National and International Response) **H**-High (Full State Response with National Support) **M**-Moderate (County Response with State and National Support) **L**-Low (Local and County Level Response)		**PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US** (Varaibles are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	**LIKELY** Probability of Occuring 70%-90%	**OCCASSIONAL** Probability of Occuring 30%-69%	**SELDOM** Probability of Occuring 10%-29%	**UNLIKELY** Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	**CATASTROPHIC** Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

Salmonella would not normally be classified as a bioterror threat. Outbreaks of salmonella occur with some regularity in the US as a foodborne illness. A result of improper sanitation techniques during food preparation leads to many outbreaks across the US. The Oregon attack demonstrates the use of a regularly occurring disease in manner consistent with bioterrorism. So the IDTM for salmonella is not based on bioterrorism but in its regularly occurring state. Outbreaks occur occasionally and their effects are marginal based on the population infected. This disease is more likely to have a higher impact on small children and the elderly, but there are treatment protocols available. The IDTM rating would be low (table 7).

Measles

Vaccine preventable diseases are the most disturbing category of threats to the biosecurity of the US. During the pre-vaccine era, Measles historically infected three to four million Americans each year resulting in 400 to 500 deaths and 48,000 hospitalizations. There was a 99 percent reduction in the number of annual measles cases after mandatory vaccinations went into effect, and in 2000 Measles was considered eliminated in the US.

In 1998, a British medical doctor, Andrew Wakefield, was conducting research aimed at linking autism disorders to the MMR vaccine. When the work was published it had an immediate effect upon the public in Great Britain and in the US. Vaccination rates plummeted among children in some areas to below 80 percent, well below the recommended percentages needed for herd immunity.[79] Celebrities such as Jenny McCarthy heard of this link between autism and vaccines, and served as spokespersons to the public and the anti-vaccine movement gained momentum. Wakefield's results were almost immediately disputed due to research error. His sample size was only 12 individuals, of which five were already showing developmental issues prior to receiving any vaccine.[80] More of his research was falsified as a means to create a scare among the public to entice a lawsuit against vaccine makers. The research has since been retracted

[79] Levi et al.

[80] T. S. Sathyanarayana and Chittaranjan Andrade. "The MMR Vaccine and Autism: Sensation, Refutation, Retraction, and Fraud," *Indian Journal of Psychiatry* 53, no. 2 (April 2011): 95-96.

and Wakefield's medical license has been taken from him, but the damage to public health had been done.[81]

In the decade between 2000 and 2010, the majority of measles reported cases in the US were from international travelers. In 2011, there were 16 outbreaks of measles across the US resulting in $2.7 million to $5 million economic burden to public health institutions. In 2014, there were more than 600 measles cases reported. The largest measles outbreak in 2015 was a large, multi-state outbreak linked to an amusement park in California.

The outbreak likely started from a traveler who became infected overseas, then visited the amusement park while infectious and spreading the disease. A total of 125 individuals were confirmed as a result of infection at the amusement park, and a vast majority either were unvaccinated (49) or had an unknown vaccination status (47). Although the initial carrier of the disease was never identified analysis by the CDC showed that the measles virus type in this outbreak was identical to the virus type that caused the large measles outbreak in the Philippines in 2014.

States currently control the policies for vaccination standards for children entering school. All states have a clause for medical exemptions, that is to say giving the vaccination to a person could do more medical harm and the risk is therefore greater than the benefit. An example would be someone with an immunosuppressed condition who may not have a healthy enough immune system to fight off infections. Many states also allow either a religious exemption that allows parents to choose not to vaccinate their children based on some principle that vaccines and medicine would violate their religious

[81] Ibid., 95-96.

teachings, while some states may offer personal exemptions, which are parents deciding what is right for their children with regard to vaccination. These exemptions refer to vaccine requirements for children entering the public school system.

Prior to the recent measles outbreak in California, 48 states allowed exemptions or a combination of exemptions based on religious or personal beliefs, and only two states had stricter requirements that only allowed medical exemptions.[82] Since the measles outbreak, California has since changed position and introduced legislation that will be enacted for the next school year eliminating religious and personal exemptions for children entering public schools.[83] Others states are also introducing legislation that would eliminate personal and-or religious exemptions.

The measles outbreak in California highlights the risk that globalization has on vaccine preventable disease. There was a similar incident to the outbreak in California at a megachurch in Texas, a state which allows religious exemption.[84] One family of parishioners had traveled internationally to a country endemic with measles and one of the children became infected. During the incubation period of the disease, the child returned to the states and unknowingly spread the disease to other non-vaccinated parishioners in the church. There were no deaths but the incident caused the pastor of the

[82] Levi et al.

[83] California State Legislature.

[84] Emily O. Lee, Lindsay Rosenthal, and Gabriel Scheffler, “The Effects of Childhood Vaccine Exemptions on Disease Outbreaks,” Center for American Progress, November 14, 2013, accessed May 21, 2016, https://www.americanprogress.org/issues/healthcare/report/2013/11/14/76471/the-effect-of-childhood-vaccine-exemptions-on-disease-outbreaks/.

church to change course on vaccination by saying they do not go against the teaching of god and ultimately offered a vaccine clinic for the remainder of the parishioners.

The threat from vaccine preventable disease is affected most by human migration and international travel. Americans traveling overseas or foreign travelers visiting the US may encounter individuals in other countries that are endemic to these diseases. When these travelers come back to the US they may unknowingly be infected with one of the various disease agents that cause these diseases. These individuals may or may not be showing symptoms but they can still be infectious as was the case in California with the most recent outbreak of measles.

Human migration will also have an effect on the magnitude of cases of vaccine preventable illnesses. There are a growing number of illegal immigrants coming from countries other than Mexico. These countries include those in Central and South America, the Caribbean, and the Asian-Pacific areas. These immigrants are often migrating from countries that are lacking significant public health capability and therefore are at a greater risk for being a carrier for one of the vaccine preventable diseases.

The likelihood that a vaccine preventable disease will cause an outbreak within the US is high (frequent on the IDTM). So long as the herd immunity, within states that offer religious and personal exemptions, remains below the threshold recommended for a given disease (table 8) the threat to the public will remain extremely high.

Table 8. R_0 and “Herd Immunity” Thresholds

R_0 and "Herd Immunity" Thresholds for Some		
Disease	R_0	Herd Immunity Threshold
Measles	12-18	92-94%
Pertusis	12-17	92-94%
Mumps	4-7	75-86%
Smallpox	6-7	83-85%

Source: Cynthia G. Whitney, Fangjun Zhou, James Singleton, and Anne Schuchat, “Benefits from Immunization during the Vaccines for Children Program Era-United States, 1994-2013,” *Morbidity and Mortality Weekly Report (MMWR)* 63, no. 16 (April 2014): 352-355.

Note: This table displays the relative vaccination percentage known as “herd immunity” required to limit the probability of an outbreak from occurring. Herd immunity is driven by the R_0 (R Naught) quotient which reflects the virulence of the pathogen. R naught the number of secondary cases that would be estimated from a single case in a susceptible population.

The severity of vaccine preventable disease is considered marginal on the IDTM. The mortality from these diseases remains low with the advancement of treatment options. The true impact of vaccine preventable disease remains in their economic impact to states and the US as a whole. Monitoring disease outbreaks, treatment within healthcare facilities, rising insurance costs, and burden to the employee—employer sector can be significantly high. Childhood vaccination programs could prevent 33,000 deaths per year and save an additional $43 billion in total costs.[85] The CDC estimates that vaccinating all non-medically exempt children would prevent 322 million illnesses, avoid

[85] Sandra W. Roush and Trudy V. Murphy, “Historical Comparisons of Morbidity and Mortality for Vaccine-Preventable Diseases in the United States,” *JAMA* 298, no. 18 (November 2007): 2155-2163, doi:10.1001/jama.298.18.2155.

732,000 deaths and save over $1.4 trillion in total cost burden of disease.[86] With respect to vaccine preventable disease, "an ounce of prevention is worth a pound of cure."

The probability of vaccine preventable disease is likely. US states that allow for religious and personal exemptions for vaccination programs have shown a decrease in the herd immunity of their communities. As globalization and international travel increase, the potential for non-vaccinated individuals to come in contact with infected individuals' increases. The severity of the effects of these diseases is marginal. Many of these diseases have a low mortality rate as treatments protocols have improved. Many vaccine preventable diseases have higher R_0, therefore, their ability to spread within a susceptible population increases. Based on these assessments, the overall biosecurity threat level for these diseases is listed as high (H).

[86] Levi et al.

Table 9. IDTM for Measles

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels **EH**-Extremely High (National and International Response) **H**-High (Full State Response with National Support) **M**-Moderate (County Response with State and National Support) **L**-Low (Local and County Level Response)		**PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US** (Varaibles are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	**LIKELY** Probability of Occuring 70%-90%	**OCCASSIONAL** Probability of Occuring 30%-69%	**SELDOM** Probability of Occuring 10%-29%	**UNLIKELY** Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	**CATASTROPHIC** Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

Measles outbreaks occur with regularity. Its effect historically would place risk at critical, however, there are now effective vaccine and treatment protocols which limit the effects of an infection. Herd immunity plays a factor in public preparedness as a protection factor; however, as herd immunity percentages decrease, severity of outbreaks will occur. For these reasons measles has been given an IDTM rating of moderate, but there are multiple mitigation strategies such as vaccinations and antibiotics that would decrease the residual risk into a low category.

Hospital Acquired Infections

There is some concern that some antibiotic resistant diseases can pose a threat to the general population of the US. Antibiotic resistant tuberculosis is an example of one such disease. Tuberculosis was a widely common disease in the US before the advent of antibiotics, and was a significant cause of mortality. The bacteria responsible for tuberculosis affected the lungs of the individual and caused death through the continual damage to the lung tissue.[87] The threat of tuberculosis was largely eliminated when antibiotics were discovered that treated the disease. Through the improper use of antibiotics and the adaptability of the bacterium, antibiotic resistant strains of tuberculosis have been occurring globally. In the US, an outbreak of antibiotic resistant tuberculosis would cause more expensive treatment protocols to be enacted, thus burdening the healthcare sector.[88]

Hospital acquired infections are another menace that are adding to the rising costs of healthcare. Patients in a hospital setting are often at a decreased level of health and many are either suffering or carrying some form of communicable disease. Methicillin Resistant Staphylococcus Aureus (MRSA) and Clostridium difficile (C.diff) are two common infections that are acquired in a hospital setting.[89] The problem with these diseases is that they infect individuals who are in the hospital for treatment for other conditions. These secondary infections cost millions of dollars annually in additional healthcare costs and are a measure of the quality of care in hospitals.

Hospitals that pass a Joint Commission accreditation process have been evaluated on the level and quality of care that they deliver to their patients. One big focus is with respect to hospitals acquired infection because of the prevalence of them and because they are a direct result of the quality of care and of the facilities of the hospital.

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[87] The Center for Food Security and Public Health, “Anthrax.”

[88] Scott.

[89] Ibid.

Accrediting bodies such as the Joint Commission are tools to help mitigate the risks from opportunistic disease and thus lessen the overall likelihood of them affecting a significant amount of the population.[90]

The probability of the general public becoming infected with an opportunistic disease is rated overall as seldom. These infections will occur but the chance of affecting a significant number of residents at a given time would be extremely rare. These infections most often occur in patients being treated within a hospital setting which further narrows the opportunity for infections. The severity of opportunistic disease is rated at marginal. The most significant impact is to the economy. Secondary infections add to the rising costs of healthcare but the indirect impacts are difficult to measure. Control measures for these types of infections include accrediting bodies such as the Joint Commission.[91]

Organizations such as the Joint Commission make hospital acquired infections a reportable condition. If a hospital garners too many reportable conditions, they may have to justify their actions and report solutions or risk losing their accreditation status. Medical insurance companies also play a major role in limiting the occurrence of these types of infections. Insurance companies may refuse to reimburse payments to hospitals for the treatments of opportunistic infections. Again, secondary infections are a direct result of the quality of care received in the hospitals, and if a patient receives a secondary infection then it is the hospital that can be held liable for the cost of treating the

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[90] The Joint Commission, "About Our Standards," accessed May 24, 2016, https://www.jointcommission.org/standards_information/standards.aspx.

[91] Ibid.

individual.[92] This forces hospitals to routinely evaluate the quality of services offered to their patients.

Table 10. IDTM for Hospital Acquired Infections

INFECTIOUS DISEASE THREAT MATRIX						
Biosecurity Threat Levels **EH**-Extremely High (National and International Response) **H**-High (Full State Response with National Support) **M**-Moderate (County Response with State and National Support) **L**-Low (Local and County Level Response)		**PROBABILITY OF DISEASE OUTBREAK TO OCCUR IN US** (Varaibles are #Vectors, # people (globalization), susceptibility of population)				
		INEVITABLE Probability of Occuring 90%-100%	**LIKELY** Probability of Occuring 70%-90%	**OCCASSIONAL** Probability of Occuring 30%-69%	**SELDOM** Probability of Occuring 10%-29%	**UNLIKELY** Probability of Occuring <10%
SEVERITY OF DISEASE OUTBREAK (Variables are mortality rates, R_0 values, economic impact, treatment availability)	**CATASTROPHIC** Mortality: >30% Transmissability R_0: >7 Economic: Will result in Trade/Travel Restricitions	EH	EH	EH	H	M
	CRITICAL Mortality: >15% Transmissability R_0: >5 Economic: Might result in Trade/Travel Restricitions	EH	H	H	M	L
	MARGINAL Mortality: >5% Transmissability R_0: >3 Economic: Likely local response sufficient Treatment readily available in quantity for	H	H	M	L	L
	NEGLIGIBLE Mortality: >0-5% Transmissability R_0: <2 Economic: Contained within local response Treatment readily available for multiple	M	L	L	L	L

Source: Created by author.

The probability of infection from an opportunistic disease is roughly 4 percent of hospitalized individuals each year and is assessed as unlikely.[93] The severity of these infections results in 75,000 deaths each year and places a significant burden on total costs

[92] Centers for Medicare and Medicaid Services, "Readmissions Reduction Program (HRRP)," accessed May 24, 2016, https://www.cms.gov/medicare/medicare-fee-for-service-payment/acuteinpatientpps/readmissions-reduction-program.html.

[93] Scott.

for the healthcare industry and is therefore assessed as marginal.[94] The overall biosecurity threat is therefore assessed as low (L).

Implications for US Forces

The Army Medical Department conducts infectious disease research through the US Army Medical Department Research and Material Command (USAMRMC). The Military Infectious Diseases Research Program (MIDRP), a subcomponent of USAMRMC, has the mission to protect the US Military against naturally occurring infectious diseases via the development of United States Food and Drug Administration approved vaccines, drugs, and diagnostic assays and Environmental Protection Agency approved vector control protection systems such as chemicals to prevent transmission of infections by insects, ticks, etc.[95] The US Military has had notable successes in this undertaking (since World War I, deaths from naturally occurring infections have not exceeded deaths due to combat injury in wartime) although infectious disease is still the number one reason for Soldiers seeking medical care in combat. MIDRP's role is of continuing importance because diseases such as Malaria, Dengue, diarrhea, leishmaniosis and many other tropical diseases continue to have an adverse impact on military operations and the health of service members. And as future pathogens gain a foothold, they too get added to the list of diseases that can have a significant impact on military force projection. One such disease that has been getting a lot of press as of late is Ebola.

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[94] Scott.

[95] U.S. Army Medical Research and Material Command.

MIDRP efforts have been paramount in the treatment for those inflicted with the disease but the MIDRP is headlining efforts to develop a vaccine against Ebola.[96]

Infectious diseases have a significant impact on operational forces. More service members are hospitalized for infectious diseases than those who are wounded in combat. Infectious diseases also place a significant burden on the medical logistical system for people requiring treatment or hospital space. The loss of personnel to infectious diseases reduces operational readiness and effectiveness by requiring replacement troops. Some of the more contagious and infective disease organisms have been used by other countries as weapons. The strategic importance of conducting research on global infectious has placed an emphasis on the US Military to fund programs that will aid in the overall force health protection of service members.

Cutaneous leishmaniosis, a disease transmitted by sand flies, had a major impact early in Operation Iraqi Freedom. More than 1,700 personnel were diagnosed with this disease, and many had to be evacuated to the US for treatment, which significantly impacted treatment facilities. In one incident, an Army unit was positioned near the Tigris River Valley in Tikrit, Iraq. This unit's Soldiers did not properly employ their issued Permethrin-treated bed nets in an area known to be afflicted with sand flies. This unit had 20 percent of their Soldiers contract leishmaniosis and had to be evacuated for treatment to Walter Reed Army Medical Center in Maryland.[97] This had a significant impact on the unit's readiness and had a negative effect on the unit's combat ability until further reinforcements could arrive.

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[96] U.S. Army Medicine, 1-13.

[97] U.S. Army Medical Research and Material Command.

The impact of Malaria was seen in Korea and Vietnam, where 25 percent of all Army troops suffered with this disease. Malaria remains a militarily-relevant disease as evidenced in 2003 when 44 percent of 268 Marines conducting a two-week mission in Liberia were rapidly rendered ineffective due to Malaria.[98] About 40 of them were evacuated to the US for treatment, and four developed severe symptoms.[99] Fortunately, no one died from the infections. For these reasons the development of a vaccine against Malaria and the continued development of treatment drugs remains a focal point of the MIDRP.

The MIDRP has supported HIV vaccine research and development since 1985 as HIV remains a significant threat to service members deployed overseas and is a major source of regional instability in areas of US force protection. The MIDRP HIV and Malaria research programs are heavily leveraged to coordinate with the efforts of other US Government agencies. MIDRP has ongoing partnerships with commercial, governmental and non-governmental agencies to combat infectious disease.

The Army Medical Department planners conduct their own medical mission analysis and medical threat brief when notified of a units pending mission to an austere environment. The analysis follows the Military Decision Making Process in gaining a situational understanding of the threats to force health protection from understanding the effects upon forces from climate and terrain, from environmental hazards commonly found in the area of operations, animal threats, and the threats from infectious disease.

[98] U.S. Army Medical Research and Material Command, "Military Infectious Diseases Research Program (MIDRP)," March 22, 2010, accessed May 23, 2016, http://mrmc.amedd.army.mil/.

[99] Ibid.

The information gathered is then presented in a risk assessment in a similar manner to this paper, so that maneuver forces can determine the potential effect of these threats to mission accomplishment. It would benefit maneuver forces if the medical threat planning was being conducted alongside the Intelligence Preparation of the Battlefield of mission analysis.

Summary and Conclusions

The current threat from infectious disease is significant. The threats identify a potential for catastrophe to both the health of the public of the US and to the nation's economy. Bioterrorism and emerging infectious diseases provide the greatest variability in terms of complexity and chaos. A determined enemy with a simple capability can wreak havoc upon the agricultural institutions that drives a great portion of the US economy.[100] An infection of British livestock caused significant economic distress that was felt for years afterwards. A similar attack generated against a susceptible US population could cause significant panic and distress which would challenge the public health infrastructure created to protect them.

Vaccine preventable infections have been shown to be a known simple problem. Vaccines have been created to prevent the occurrence of infection and have been shown to be highly effective. The herd immunity of the population has protected those that cannot or choose not to receive the vaccinations; however, the number of those electing for an exemption from receiving vaccination continues to grow. These individuals are

[100] Mark Wheelis, Rocco Casagrande, and Laurence V. Madden, "Biological Attack on Agriculture: Low-Tech, High-Impact Bioterrorism," *BioScience* 52, no. 7 (2002): 569-576.

reducing the overall herd immunity of the country and placing themselves and those around them at unnecessary risk to infection. States control the policy for granting personal, religious and medical exemptions from disease, but the measles outbreak in California and the resulting change in policy showcase the need to close the many exemptions to vaccine policies. Changing policy to close personal and religious exemptions could save billions of dollars in overall healthcare spending.[101]

[101] Matthew M. Davis et al., "Childhood Vaccine Purchase Costs in the Public Sector: Past Trends, Future Expectations," *American Journal of Public Health* 92, no. 12 (2002): 1982-1987.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This research reviewed the overall threat of infectious disease to the general public of the US. The research looked at disease variables that have an impact upon preparedness and potential responses to infectious disease. The variables can be influenced by climate change, global human movement, the improper following of medical recommendations and bioterrorism. While these variables present challenges to biosecurity against infectious disease, they can also been viewed as areas for future research.

Climate change poses a significant threat to the biosecurity of the US and to populations globally. While the causes of the change in climate are disputed, the fact that change is occurring is not. This change will potentially change the patterns of severe weather events in local environments, influencing the migration of people and the diseases they carry. Climate change is also affecting the range of vectors that transmit many diseases. The three genera of mosquitoes responsible for the most significant vector born disease, the *Culex*, *Anopheles*, and *Aedes* mosquitoes, have seen their ranges extend north and south from the equator. The extended range of habitat presents a threat to the US. It is only a matter of time before there is enough disease residing in the population of both mosquito and the human population for the disease to become endemic in new areas.

Threats such as Zika, Malaria, West Nile, Dengue, and Chikungunya will increase as they are introduced to a new susceptible population.[102]

Global human movement is spreading diseases that were once limited by geography. Infectious disease outbreaks spread when global travelers visit countries where these diseases are still endemic. Incubation times for many of these diseases allow infected individuals to travel and come into contact with significantly more people before showing any symptoms of disease. Ebola was brought to the US by one such traveler returning from Liberia who sought treatment for an unknown illness at an emergency room. This individual unknowingly infected two nurses that treated him.[103]

Opportunistic diseases cause significant strain to the healthcare industry. Parents who refuse to vaccinate their children due to an incorrect correlation with autism place their children at greater risk. These children have been relatively protected because of the greater population's relative herd immunity that has built up since vaccinations were introduced. As more and more parents refuse to vaccinate their children, the overall herd immunity decreases placing more and more children at risk. Events like the measles outbreak in California are expressive of this danger.

Hospital acquired infections, and diseases that have promulgated as increasingly more drug resistant present a challenge to our healthcare system. The increasing costs to combat these infections have an effect upon the reimbursement rates and overall medical insurance costs to the greater population. Antibiotics have long been overused to treat

[102] Ronald Rosenburg, "Threat from Emerging Vectorborne Viruses," *Emerging Infectious Diseases* 22, no. 5 (May 2016): 910-911.

[103] Centers for Disease Control and Prevention, "Cases of Ebola Diagnosed in the United States."

benign conditions, and infectious disease organisms have adapted and more “superbugs” are on the horizon. Research costs to find new treatments and the increased direct costs to treat individuals infected with the “superbugs” will further stress the healthcare community.

The threats from bioterrorism are profound. Bioterror threats, if realized, can be of the magnitude of a nuclear device being detonated in a large urban area. In the hands of a determined enemy, biological agents can be easily reproduced and disseminated to their target audience. Bioterrorism threatens human populations, the economy, and agriculture.[104]

Purpose of Research

The purpose of this study is to evaluate the threat of infectious disease to the biosecurity of the US population with respect to climate change, globalization, human migration and unvaccinated populations. This study will seek to identify gaps in biosecurity. The gaps could identify needs for further research, potential mitigation strategies, and provide for an overall risk assessment for a disease.

[104] Cupp, Walker, and Hillison, 97-105.

Interpretation of Results

Table 11. Assessed Threats using the IDTM Model

Disease	IDTM Rating	Cynefin Rating	Comments
Influenza	High	Chaotic	Moderate mortaltiy in susceptible populations, high R_0, highly influenced by globalization
Botulism toxin	Extremely High	Complicated	High mortality, ease of production and dissemination, no treatments exist
Ebola	Extremely High	Chaotic	High mortality, low R_0, remains in bodily fluid after death for prolonged periods of time, treatment available at very high cost
Anthrax	High	Complex	High mortality, highly resilient in weaponized form, easily disseminated, has been used as a bioterror weapon, treatments slightly effective against weaponized forms
Smallpox	Extremely High	Complex	Elevated mortality, susceptible population, moderate R_0, few specimens known to exist, vaccine exists but not part of schedule
Drug-resistant Tuberculosis	Moderate	Complicated	Moderate mortality and morbidity, moderate R_0, susceptible population in hospital setting, treatments are diminishing as drug-resistance increases
Measles	Moderate	Simple	Low mortality, increasing susceptible population, high R_0, globalization is significant variable, vaccine exists
Mad Cow Disease	Extremely High	Complex	High R_0, susceptible population of animals, influence multiple economic and social components, no treatment, animlas must be destroyed
Pertusis	Low	Simple	High morbidity, susceptible population(children), high R_0, vaccine exists
Malaria	Moderate	Chaotic	Moderate mortality and high morbidity, highly influenced by climate factors, treatments exist for some species
Chikungunya	Moderate	Chaotic	High morbidity, vector influenced by climate factors, no vaccine available
West Nile	Moderate	Chaotic	Low mortality, vector influenced by climate factors, no vaccine available
Cryptosporidium	Moderate	Complicated	Low mortality in susceptible population (children), moderate R_0, resistant to chlorination and many water treatments
Rabies	Low	Chaotic	High mortality, moderate R_0, animal to human transmission relatively rare, no treatments exist
Dengue	Low	Chaotic	High morbidity, vector influenced by climate factors
HIV	Moderate	Complicated	Decreasing mortality, high morbidity, moderate R_0, high prevalence, treatments exist but high cost

Source: Created by author.

Note: This table compares the initial biosecurity threat identified by the IDTM of diseases listed in Table 1 and Table 2 with their associated categorical problems identified by the 4-quadrant system problem solving method.

The IDTM is a useful tool to identify the initial risk of a particular infectious disease. Table 11 shows the many diseases from the CDC's Nationally Notifiable List of Infectious Disease. The risks identified are useful for situational understanding of the infectious disease environment. Table 11 compares risk with the problem categories of the Cynefin 4-quadrant model. Comparing diseases using these two systems provides insight into which diseases should be the priorities for resources. Comparing categories in this way can also serve to predict the resource requirement necessary to address changes to the infectious disease environment.

A disease such as measles is highly contagious, causes some mortality, and is costly to treat. Measles is a vaccine preventable illness, which poses a moderate risk using the IDTM. Protecting against measles is a relatively simple problem. If the greater percentage of a population is vaccinated, the overall population is protected by the resultant herd immunity. If resources are not allocated to close current vaccination gaps, measles may become a more complex or chaotic problem, and once again threaten the biosecurity of the US.

Vector borne diseases such as Malaria and Zika have an IDTM risk assessment of high, and can be categorized as chaotic problems, which means there is no easy solution to solve them. Problems that are chaotic and have high or extremely high risk assessments require extensive resources and timely intervention. They are likely to garner the attention of the public and divert resources from other prevention efforts.

Prioritizing resources is necessary to address gaps in biosecurity. Table 11 illustrates how risk assessment can help civilian and military authorities prioritize resources to combat the threats from these diseases. Military leaders can use these tools to assess which threats require additional research and which threats require the attention of Geographic Combatant Commanders. These tools can help strategic and tactical commanders gain better situational understanding of the infectious disease environment and develop mitigation strategies. Infectious diseases have historically caused more casualties than direct combat and the presence of endemic infectious disease in the environment should be clearly articulated to tactical commanders.

As Defense Support of Civil Authorities and global stability operations increase so too must the military pay attention to prevention, preparation, and response. Prevention includes a global outreach to increase surveillance and research capability at the source of many disease outbreaks. Research is always vital to understanding the genetic makeup and the virulence threat factor of diseases. Preparedness encompasses the response plans within the National Response Framework, or Defense Support of Civil Authorities that seek address pandemic disease with an appropriate response. Response is the allocation of resources to combat an outbreak event. These include response personnel and increasing the capacity of the National Strategic Stockpile of medications and treatment items.

Response plans can also work in unison with local and state public health departments. Outbreaks of vector borne diseases and diseases spread by globalization and migration may begin in small or rural communities. Small communities often lack resources to prepare and respond to outbreaks. The IDTM provides a tool which local and state health departments can use to prioritize the allocation of resources to match actual threats they are most likely to encounter.

The primary and secondary research questions presented at the beginning of this study asked how we can assess the biosecurity threat; the magnitude and scope of the biosecurity threat, and asked if there were any tools used by civilian or government agencies to assess the threat. Through the course of this study the questions were answered. The IDTM was created combining Army Composite Risk Management, the WHO's Rapid Risk Assessment of Acute Public Health Events, and the CDC's assessment of infectious disease risks. The IDTM can be used to assess the magnitude of threat and identify potential response levels.

The Cynefin framework comparison is beneficial because it can help identify the complexity of an infectious disease problem in order to inform resource allocation to react to immediate problems and to identify and mitigate problems that may emerge over time given the effects of globalization, climate change and human migration.

Recommendations for Further Research

This study identified two-areas for additional research: a communications strategy that informs the public of risk from infectious disease and creating an infectious disease threat and mitigation template for military forces from the strategic to the tactical level.

A communications gap was identified with vaccine preventable illness. Through various media outlets disease such as measles and pertussis have been emergent in the US. These diseases create a significant burden to the healthcare system. The resources that average civilians utilize for information are not always accurate or based on evidence. An information management and communications strategy that any civilian can use to increase knowledge of infectious disease should be further researched. Increasing research in these areas will close gaps presented by misinformation.

Tactical commanders have many obstacles that impede situational understanding of disease threats in their environments. Medical threats are often buried deep within higher level operations orders and annexes. It is the responsibility of a commander's staff to develop situational understanding including that from infectious disease threats. Force health protection is a function of Army Medical Department personnel, and at the tactical level, health service officers are often junior and inexperienced. To assist in the creation of proper situational understanding, IDTMs and mitigation strategies should be developed by the staffs of combatant commanders for dissemination to units operating within their area of operations. The resultant IDTMs could be utilized by Army Medical Department personnel at all levels (strategic to tactical) to give a focused assessment to commanders in a format that is familiar. Commanders at all levels are familiar with Army Composite Risk Management. Commanders may not be familiar with traditional medical assessment tools or briefs. IDTMs can close the gap by presenting a complete infectious disease threat analysis to the commanders so that they can then mitigate or assume proper risks.

Summary and Conclusion

Infectious disease has plagued humankind since ancient times. Even in this era of modern technology and vast resources, infectious disease still causes global mortality and morbidity. In the US vaccines, treatment protocols and response procedures have significantly reduced the burden of infectious disease. Variables such as climate change and globalization are impacting hard won gains in the biosecurity of the US population. As vectors and people spread, diseases are going to spread with them. This places a larger population of the US at risk from infectious diseases. Finding an efficient and effective means to allocate the right resources, against the right disease, and at the right time should be a focal point to maintain the biosecurity of the US population.

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